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The Modifications of the Kjeldahl Method For the Quantitative Determination of Nitrogen.

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The element nitrogen is an absolute essential for organized matter, since it is a constituent of the proteins which occur in all forms of plant and animal life. Nitric acid and the nitrates play a prominent part in the arts, especially in the manufacture of fertilizers and in the preparation of nitro-glycerin, gun cotton and aromatic nitro compounds for high explosives. Nitrogenous compounds form the greater part of the large and growing family of coal tar dyes, among which may be mentioned those triumphs of synthesis, artificial indigo and alizarin. Synthetic

organic chemistry has given to medicine a host of remedies which contain nitrogen, such as antipyrine, antifebrin and phenacetin. Nitrogen is found in the alkaloids, in prussic acid—an exceedingly virulent poison; in ammonia—a powerful base; in various products of animal and vegetable origin, such as mustard oil and the derivatives of uric acid, and in a great series of synthetic compounds like the osazones which have been so helpful in the study of the structure of the sugars.

The quantitative determination of an element so widely distributed is of the utmost importance and has been the subject of careful study by many investigators. The methods of analysis fall into three classes, represented by Dumas, Will and Varrentrapp and Kjeldahl. The year 1908 marks the twenty-fifth anniversary of the publication of the original method of Kjeldahl.

The first method for the quantitative determination of the nitrogen content of an organic compound was the absolute method of Dumas. He heated the compound with cupric oxide in an atmosphere of carbon dioxide, reduced any oxides of nitrogen by means of a glowing spiral of metallic copper, passed the gases through a solution of potassium hydroxide and measured the volume of residual nitrogen.

Later on, Will and Varrentrapp devised a method for obtaining the nitrogen in the form of ammonia by heating the nitrogenous compound with soda-lime to redness; the ammonia was collected in hydrochloric acid and weighed as ammonium chloroplatinate. Peligot modified this process by using a known amount of standard acid, and then titrating the excess of acid. The methods of Dumas and Will and Varrentrapp required that the compound be in a fine state of division; solutions had to be evaporated to dryness and the residue finely divided.

Kjeldahl (1) worked on brewery materials and wished to determine the nitrogen content of various solutions without evaporating them to dryness. First he tried Wanklyn's method for determination of albuminoid nitrogen, which depends on distillation with alkaline permanganate; the yield of nitrogen was incomplete. Better results were obtained by boiling with potassium permanganate and dilute sulphuric acid, making alkaline with a fixed alkali, distilling into standard acid, and titrating the excess of acid. Finally the substance, whose nitrogen content was to be determined, was heated with concentrated sulphuric

acid and completely oxidized with permanganate. Kjeldahl says: "The principle of the new method, therefore, is to heat the substance in question for some time with a sufficient quantity of concentrated sulphuric acid to a temperature which is close to the boiling point of the acid, and then to oxidize the solution thus obtained with an excess of dry, powdered permanganate." He recommends heating with sulphuric acid, to which some fuming sulphuric acid and phosphoric anhydride have been added, for two hours. The dark solution is to be removed from the flame and the oxidation is to be completed by means of an excess of dry, finely divided potassium permanganate, which is added, a little at a time, in the form of a stream of dust. The dark solution becomes lighter, then colorless, finally dark green, or blue green if phosphoric anhydride be present. The solution may be heated gently, but not strongly, or nitrogen will escape. Kjeldahl diluted the solution, transferred to a distilling flask, made alkaline with a fixed alkali after adding zinc turnings to prevent bumping, distilled into a known volume of standard acid, added potassium iodide and iodate and titrated the liberated iodine with standard sodium thiosulphate. The per cent. of nitrogen was then calculated. Kjeldahl published excellent results on the determination by his method of the nitrogen content of twenty-three aliphatic and aromatic compounds, as well as naturally occurring bodies. Certain alkaloids, cyanogen and nitro compounds, gave poor results.

Heffter, Hollrung and Morgen (2) made two determinations of the nitrogen content of sixty-five substances by the method of Will and Varrentrapp, and duplicate determinations on the same substances by Kjeldahl's method. The means of the determinations by the two methods checked well, the average difference being 0. 084%. The Kjeldahl method gave more nitrogen in 94% of all the determinations. They digested 1 to 1.5 grams of the substance with 2 grams of phosphoric oxide and 20cc. of a mixture of 4 volumes of pure concentrated sulphuric acid and 1 volume of the fuming acid. Heat was applied with a small flame until foaming ceased; then the solution was boiled, since this is essential for complete oxidation. The maximum period of digestion was five hours.

Petri and Th. Lehman (3) applied the process of Kjeldahl, including oxidation with potassium permanganate, to the de-

termination of the nitrogen content of ammonium sulphate, urea, uric acid, hippuric acid, kairin A (ethyl hydroxytetrahydraquinoline), and normal, diabetic and albuminous urines. They distilled the ammonia in a current of steam.

Pflüger and Bohland (4) digested urine with a mixture of equal parts of concentrated and fuming sulphuric acid, omitting the oxidation with permanganate. In a later paper (5) they recommend digestion of urine with fuming sulphuric acid.

Kreusler and Henzold (6) noticed that, during the distillation, the steam, which passed over with the ammonia, dissolved fixed alkali from the walls of the glass condenser, which neutralized the receiving acid and so caused a result which was too high. Kreusler (7) called attention to the fact that fuming sulphuric acid carries oxides of nitrogen, which reduce to ammonia during the digestion and thus increase the percentage of nitrogen. He used a solution of 200 grams of phosphoric oxide in 1 liter of rectified sulphuric acid.

Dafert (8) concluded that the sulphuric acid removes hydrogen and oxygen from the organic body in the proportions necessary to form water. The heating of the resulting carbonized mass with sulphuric acid evolves sulphur dioxide, which reduces the nitrogenous substance; the resistant nitrogen compounds thus formed are decomposed on the addition of potassium permanganate with the production of ammonium compounds. The quantity of ammonia formed depends essentially upon the length of the period of digestion; if this be sufficiently long, nearly all nitrogenous bodies will allow the complete conversion of their nitrogen content into ammonia. However, since the period of digestion, required by a new compound, cannot be foreseen in any way but must be ascertained in each case by special examination, the Kjeldahl method cannot replace entirely the method of Dumas. Dafert later (9) divided nitrogenous compounds into two classes. The first class may be examined by the Kjeldahl method without any previous reduction or other treatment; to it belong the amines, ammonium compounds, pyridine and quinoline derivatives, alkaloids and bitter principles, proteins and allied bodies. The second class includes all compounds which require a previous treatment, such as nitro, nitroso, azo, diazo, and amidoazo compounds, hydrazines and all the compounds of nitrous and nitric acids; in a word, all those compounds in the mole-

cules of which a nitrogen atom is linked to an oxygen atom or atoms, or to a second nitrogen atom.

Czeczetka (10) recommends that a saturated solution of potassium permanganate in pure, concentrated sulphuric acid be substituted for the solid salt in the final oxidation. The permanganate solution is run slowly into the solution to be oxidized by means of a tap-funnel with a long stem. Care must be taken that the permanganate solution flows into the digested solution without falling upon the surface of the latter; otherwise the reaction occurs with explosive violence.

Bosshard (11) applied the original method of Kjeldahl with excellent results in determining the nitrogen content of allantoin, and of a number of amino acids, including leucine, tyrosin, asparagin, aspartic, glutaminic and amido-valeric acids. He cautions against the use of sodium hydroxide containing nitrate in the distillation, since the nascent hydrogen, produced by the reaction between the zinc and sodium hydroxide, reduces the nitrate to ammonia and thus increases the percentage of nitrogen. Bosshard also noticed that, whenever a great excess of zinc and sodium hydroxide solution was used, sodium hydroxide was carried over mechanically by the hydrogen gas, and was titrated as ammonia. A ball filled with glass beads failed to hold back all of the mechanically carried alkali. However, the error may be overcome by avoiding a great excess of the reagents, or by the use of a safety distilling bulb such as that invented by Pfeiffer and F. Lehmann (12) and improved by Rindell and Hannin (13), or that devised by Reitmair and Stutzer (14).

Wilfarth (15) noticed that the presence of copper salts appreciably reduced the time required for the digestion; he tested the effect of the oxides of iron, mercury, maganese, bismuth, zinc, lead and copper on the digestion of materials such as clover hay and peas. One gram of material and one gram of oxide were digested with concentrated sulphuric acid and phosphoric anhydride until a bright Rhine wine color appeared. Digestion proceeded more rapidly when the oxides were added than when they were absent. Mercuric oxide reduced the time factor to one-eighth that of the plain digestion, but mercur-ammonium compounds formed in the distilling of the ammonia and caused a loss of nitrogen. Therefore, experiments were tried with cupric oxide.

The effect of the cupric oxide depends entirely on the quantity of oxide in solution; 20 cc. of concentrated or fuming sulphuric acid will dissolve 0.1 gram of oxide, but the same volume of acid will dissolve 0.2 gram of oxide in the presence of 4 grams of phosphoric anhydride, and 0.6 gram of oxide in the presence of 10 grams of anhydride. Wilfarth states that the cupric sulphate plays a catalytic rôle in the oxidation of the organic matter. For each digestion he used either 0.5 or 1 gram of monohydrated cupric sulphate and 20cc. of a solution of 250 grams of phosphoric anhydride in 1 liter of concentrated sulphuric acid. The mixture was heated until either colorless, or a wine red, when it was oxidized with permanganate. This method was applied with success to various materials of animal and vegetable origin, such as leather and oil cake.

In a second paper (16) Wilfarth states that the time factor is almost the same when ferric oxide is substituted for cupric oxide, but both the green color of copper and the yellow one of iron mask the end point of the digestion.

Mercuric oxide is more soluble in sulphuric acid, hence acts as a better catalyser, and it possesses the additional advantage of forming a colorless solution. Oxide, free from nitrate, prepared by the wet method, should be used; for it may be substituted a chemically equivalent quantity of metal or sulphate. One gram of substance should be digested with 0.7 gram of mercuric oxide and 20cc. of a mixture of 300cc. of concentrated and 200cc. of fuming sulphuric acid, without the addition of phosphoric anhydride, until completely colorless; 0.6 gram of the oxide dissolves while the other 0.1 gram prevents bumping during the digestion. While oxidation may be completed with permanganate after the solution becomes wine red, a loss of nitrogen may then occur. When mercuric oxide is substituted for cupric oxide, the time factor for a digestion is reduced to one half. The formation of mercur-ammonium derivatives during the distillation of the ammonia is prevented by an addition of potassium sulphide solution. The Official Agricultural Chemists,in their modification of this method(17), direct the use of 25cc. of a solution of 40 grams of sulphide in 1 liter of water.

Warington (18) and Reitmair (19) have devised methods whereby the organic nitrogen alone may be determined when a mixture of an organic compound and a nitrate is the subject of

analysis. Warington directs a preliminary heating of the mixture with an excess of ferrous sulphate and strong hydrochloric acid to expel the nitric nitrogen; the solution is then evaporated to dryness, concentrated sulphuric acid is added and the digestion is carried out in the usual way to determine the organic nitrogen. Reitmair places one gram of the finely powdered mixture in a dish of tin foil, adds 3cc. of 50% sulphuric acid, stirs well with a glass rod, dries in the oven 3 to 4 hours at 60° to 80°C., then for one hour at 120°-130°C. The moist mass is now free from nitric acid, and is digested in the usual way.

Several investigators have modified the method of Kjeldahl so that it may be applied in the determination of the nitrogen content of nitrates and nitro compounds. Stebbins (20) digested 0.25 gram of material with 0.5 gram of sucrose, 2 grams of phosphoric anhydride and 20cc. of a mixture of four volumes of sulphuric acid of 66°B., and one volume of the fuming acid; oxidation was completed by means of permanganate. Results, correct to a few tenths of one per cent., were obtained with dinitrobenzol, meta nitraniline, and ortho nitrophenol.

Asboth (21) mixed 0.5 gram of such substances as azobenzol, nitrobenzol and picric acid with 1 gram of sucrose and digested with cupric sulphate and sulphuric acid, as directed by Wilfarth, without use of potassium permanganate. The same process was applied to cyanide, ferrocyanide and ferricyanide of potassium, sodium nitroprusside and ammonium thiocyanate, as well as to cyanuric acid. With nitrates, sucrose was replaced by benzoic acid; for each half gram of potassium nitrate, 1.7 grams of benzoic acid were added. Although permanganate was used to complete the oxidation, the results were low by 0.339 %. The Kjeldahl-Wilfarth process gave the best results with alkaloids. Quantitative results could not be obtained with pyridine, quinoline and cinchonine. Asboth used a solution of 350 grams of Rochelle Salt and 300 grams of sodium hydroxide in 1 liter of water in his distillations, in order to keep metallic oxides in solution.

Ulsch (22) introduced platinic chloride as a catalyser; his charge consisted of 1 gram of substance, 0.05 gram of cupric oxide, 5 drops of platinic chloride solution, which contained 0.04 gram of platinum in 1cc., and 20cc. of a solution of 200 grams of phosphoric anhydride in 1 liter of pure, concentrated sulphuric acid. This mode of digestion is more rapid than that with mer-

curic oxide; the digestion is finished when the solution takes on a pure green (not a yellow-green) color. Oxidation with permanganate is entirely omitted. Analyses are given of the nitrogen content of a number of substances of both animal and vegetable origin.

Jodlbauer (23) improved the process of Asboth for nitric nitrogen and combined with it the method of Ulsch. He replaced benzoic acid by phenol, which more readily yields nitro derivatives. Stannous chloride was first used to reduce nitrophenol to aminophenol, but did not act with sufficient energy, while zinc dust gave excellent results. Platinic chloride was used as the catalyser. From 0.2 to 0.5 gram of potassium nitrate, or the corresponding amount of another nitrate was digested for 4 hours with 20cc. of concentrated sulphuric acid, 2.5cc. of phenolsulphonic acid (50 grams of phenol dissolved in sufficient concentrated sulphuric acid to yield 100cc. of solution), 2 to 3 grams of zinc dust and 5 drops of platinic chloride solution of such strength that 1cc. contained 0.04 gram of metallic platinum. Addition of 4 grams of phosphoric anhydride to a charge reduced the period of digestion to two hours.

The Association of Official Agricultural Chemists have modified both the Kjeldahl and Gunning methods to include the nitrogen of nitrates. Salicylic acid is added to form a nitro compound, which is reduced by means of zinc dust or sodium thio-sulphate. The use of the latter reagent was first recommended by Förster (24).

Sherman (25) finds that a loss of nitric nitrogen always occurs whenever much chloride is present with the nitrate. A yield of 99.6% of the total nitric nitrogen is obtained by the official modified Kjeldahl method, if the solution of salicylic acid in sulphuric acid be cooled, added to the material and permitted to stand in contact with the same for two hours at room temperature, with frequent shaking. Zinc dust is then added, heat is applied, and the rest of the process is carried out as officially directed. The official modified Gunning method yielded but 97.8% of the total nitric nitrogen, although the acid mixture was cooled, the thiosulphate was added slowly and with cooling and shaking, and the digested material was boiled for some time after it became colorless.

Kulisch (26) determines the nitrogen content of wine,

must and yeast by digesting with metallic mercury and a mixture of equal volumes of concentrated and fuming sulphuric acid, which contains 100 grams of phosphoric anhydride in each liter. Must contains much sugar, which should be fermented by addition of so slight a quantity of yeast culture that the nitrogen content of the latter may be neglected; the fermented liquid is digested in the usual way.

The determination of the nitrogen content of coal has been studied by Schmitz (27) and Lord (28). Schmitz digests from 0.8 to 1.0 gram of coal with 1 gram of mercuric oxide and 20cc. of concentrated sulphuric acid for from 2 to 3 hours. He digests coke samples for 1 hour with 1 gram of mercuric oxide and 20cc. of concentrated sulphuric acid, then adds another gram of mercuric oxide in portions and 2 grams of finely powdered potassium permanganate in small portions. Lord digests 1 gram of coal with 30cc. of concentrated sulphuric acid and about 0.65 gram of metallic mercury. "The digestion was continued for about three-quarters of an hour after the oxidation was apparently complete, the total time being about three hours."

Arnold (29) studied the action of a mixture of sucrose, benzoic acid, cupric sulphate and mercury, with and without the addition of phosphoric anhydride, in the digestion. With the following charge:

0.5 gram substance
1.0 gram mercury (metal)
0.5 gram cupric sulphate (anhydrous)
2.0 gram phosphoric anhydride
1.0 gram sucrose
2.0 gram benzoic acid
20. cc. concentrated sulphuric acid,

a period of 60 to 80 minutes was required for digestion. Excellent results were obtained in determining the nitrogen content of alkaloids, inorganic nitrates, nitro compounds, and cyanogen derivatives. Equally good results were obtained when phosphoric anhydride was omitted from the charge, provided the period of digestion was lengthened to 3 to 4 hours Pyridine and quinoline derivatives, azo compounds and inorganic nitrites gave low values, even when oxidation by chromic acid or permanganate was resorted to, when the quantity of sucrose or of benzoic acid

was increased, or when benzoic acid was replaced by phenols, sulphonic acids or cellulose.

Gunning (30) recommends the digestion of 0.5 to 1 gram of substance with 20 to 30cc. of a solution of one part of potassium sulphate in two parts of ordinary sulphuric acid, until a colorless solution is obtained, requiring from one-half to two hours. He points out that acid potassium sulphate forms and acts upon the nitrogenous compound during the digestion exactly as would sulphuric acid heated under pressure above its boiling point. In the older methods sulphur trioxide might escape; here it is fixed and only water may escape; the sulphuric acid is concentrated, not weakened during the digestion. Gunning applied the method with success to such substances as morphine, antefebrin, peptone, bread, beer, milk and linseed cake.

Arnold and Wedemeyer (31) combined the Arnold and Gunning methods. They used:

0.5 gram substance
15. to 25 gram potassium sulphate
1. gram mercuric oxide
1. gram cupric sulphate
30. to 50. grams sulphuric acid,

and succeeded in converting into ammonia the nitrogen content of a number of compounds with which all other modifications of the Kjeldahl method are unavailable, e. g. quinoline and pyridine compounds, provided the bodies in question be non-volatile below the boiling point of sulphuric acid. When several nitrogen atoms are present in the heterocylic ring, the ease or difficulty of converting the total nitrogen content into ammonia may depend upon whether the nitrogen atoms be adjacent to or distant from each other. The former class of compounds seems to be more difficult to convert into ammonia, as is shown by experiments on members of the pyridazin, pyrimidin, pyrazin, quinazolin, cinnolin, quinoxalin, pyrazol and pyrazolin groups. In general, if the simple Kjeldahl treatment yield a lower percentage of nitrogen in a compound than does this modification, then nitrogen is contained in the ring. Certain determinations made by this method on antipyrine show that one at times may obtain concordant results and, therefore, apparently correct analyses by preserving the same conditions, while in reality the results are too low. These investi-

gators noticed that, if granulated zinc be replaced by two to three grams of zinc dust of known nitrogen content in the distillation, the use of potassium sulphide is unnecessary.

Winton, Ogden and Mitchell (32) applied the method of Arnold and Wedemeyer in determining the nitrogen content of both white and black peppers, and of their ether extract. They direct that—

1 gram substance
1 gram cupric sulphate
1 gram red mercuric oxide
15 to 18 grams potassium sulphate
25 cc. sulphuric acid

be heated gently until foaming ceases, then boiled from 3 to 4 hours. Before making alkaline in the distillation, 50cc. of potassium sulphide solution are added. Pure piperine gave results correct to within a tenth of one per cent.

Krüger (33) introduced potassium bichromate as the oxidizing agent in the digestion. From 0.2 to 0.8 gram of substance is dissolved in 20cc. of concentrated sulphuric acid with the aid of gentle warming, if necessary. After the solution has cooled, finely powdered bichromate is added in portions of 0.5 gram until 0.5 gram has been added in excess of the quantity theoretically required for complete oxidation of the substance. If carbon dioxide be evolved, even in the cold, addition of further quantities of bichromate must be deferred until the gas evolution ceases. Otherwise the entire quantity of bichromate may be added at once. The flask is next placed in a cold water bath, which is then heated. When the water boils and all the bichromate has dissolved, the flask is heated for ten minutes, with frequent shaking, upon a wire gauze, over a small flame, which need but touch the gauze. The end of the operation is recognized by the pure green color of the solution and the cessation of the evolution of gas. Frequently toward the end of the process chromic salts separate and cause the liquid to bump. Krüger states that the method yields good results with members of Dafert's first class of compounds (9). Several experiments on members of Dafert's second group lead to negative results, although the application of the method to this group is still a field for research.

Dyer (34) gently heats 0.5 to 5.0 grams of material with 20cc.

of strong sulphuric acid and a single drop of mercury until initial vigorous action has ceased, then gradually increases the heat during a period of 10 to 15 minutes, until brisk boiling begins. Ten grams of potassium sulphate are added and digestion is continued for 30 to 60 minutes when the contents of the flask become clear and colorless. For nitrates the use of phenol or, preferably, salicylic acid, zinc dust and mercury is recommended. Results are given of the analysis of a large number of aliphatic and aromatic compounds as well as cyanogen derivatives and alkaloids. Sucrose and zinc dust aided in the reduction of many refractory compounds.

Riviere and Bailhache (35) report the result of certain experiments designed to shorten the time required for decolorization with sulphuric acid in the digestion. Various substances, such as iron sulphate, vanadic, boric, molybdic and arsenic acids, were used to raise the temperature of the sulphuric acid, but in each case where the results were correct the process was too slow. Substitution of phosphoric acid for sulphuric acid yielded unsatisfactory results, even when maganese dioxide and phosphate were added to the charge. Ferric oxide and phosphoric acid gave correct results; however, the method is slower and more unpleasant than that of Kjeldahl. The only objection to the Gunning method is the relatively long time required with some substances, such as horn, for complete conversion of the nitrogen into ammonia. In the Kjeldahl method loss of nitrogen occurs if a great excess of mercury be used, and the mercury must be precipitated before distilling. Correct results were obtained with the greatest speed by digesting with sulphuric acid and 1 to 2 grams of sodium pyrophosphate for from 1 to 2 hours.

Dakin (36) directs that the substance be heated with the ordinary mixture of potassium sulphate and sulphuric acid to thorough disintegration, then allowed to cool below 100°C. A few grams of potassium persulphate are added and heating is resumed; vigorous evolution of oxygen occurs, and the black solution becomes clear. If the reaction appears incomplete, heat further, cool and add more persulphate. The persulphate must not be added to the liquid at too high a temperature; otherwise the salt will decompose too rapidly and proper oxidation will not occur. The function of the persulphate is twofold; it acts as an oxidizer and at the same time strengthens the sulphuric acid. Good results were ob-

tained more quickly with difficulty decomposable bodies like acetanilide, sulphanilic acid and the alkaloids by this method than by other methods. Dakin sums up: "It would appear that in the case of substances which are difficult to completely decompose in the ordinary way, potassium persulphate will find a useful application."

Recently the Gunning method has been modified by addition of a slight quantity of cupric sulphate to hasten the digestion. The Association of Official Agricultural Chemists (37) are considering the modification of the official method by permitting the addition of 0.1 to 0.3 gram of the crystallized salt. Hawk (38) reports that nitrogen is always lost whenever more than 0.2 gram of cupric sulphate is used in a digestion.

EXPERIMENTAL WORK ON ANTIPYRINE.

But one series of determinations of the nitrogen content of antipyrine—dimethylphenyepyrazalon—by any modification of the Kjeldahl method is to be found in the literature. Arnold and Wedemeyer (31) obtained the following results by their method:

Weight of Antipyrine used in grams.	Period of Digestion.	Per cent. of Nitrogen obtained.
0.7075	2 1/2 hours	9.6
0.6221	1/2 hour	9.69
0.658	5 hours	12.90
0.4356	2 hours	9.52

In the last experiment potassium permanganate was used for final oxidation. The results were not bettered by prolonging the digestion for 10 to 15 hours, or by subsequent oxidation with permanganate, barium dioxide, lead dioxide, or by the addition of phosphoric anhydride. A three to six fold increase of the cupric sulphate or mercuric oxide caused a loss of nitrogen. These results are considerably below the theoretic per cent., which is 14.89.

In the following experiments Jena flasks of 500cc. capacity were used for both digestion and distillation. The digested contents of each flask were dissolved in 200cc. of distilled water; a little granulated zinc was added, and an excess of concentrated sodium hydroxide solution (usually 100cc.) was poured in so that it sank beneath the solution of digested material. The flask was

connected with a safety bulb and a block tin condenser, and then the contents of the flask were mixed by shaking. To the lower end of the condenser was attached a piece of glass tubing of the same bore as the tin tube, for experience has shown that even acid of the dilution used will act upon tin and thus introduce an appreciable error. This glass tubing dipped beneath the surface of a measured quantity of $\frac{N}{10}$ sulphuric acid during the distillation proper, which was continued until bumping began, usually from 40 minutes to an hour. The Erlenmeyer flask, which contained the distillate, was then lowered so that the tubing was above the liquid, and the distillation was continued for 10 minutes, when the exterior of the tube was washed off into the flask and the contents were titrated with $\frac{N}{10}$ sodium hydroxide, using Grübler's congo red as an indicator. Whenever mercuric oxide was used in the digestion, the potassium sulphide solution was added and mixed by shaking before addition of the zinc and alkali. During several digestions, e. g. those according to Jodlbauer, and Riviere and Bailhache, it became necessary to add a slight amount of cupric sulphate to hasten the clearing of the liquid. Unless otherwise stated, the period of digestion was 5 hours. The antipyrine used was from two sources; one was a domestic brand, the other was the German "Löwenmarke." Both gave about the same percentage of nitrogen by the same method.

Antipyrine was digested with 0.7 gram of yellow mercuric oxide and 30cc. of concentrated sulphuric acid for 5 hours. No permanganate was used.

0.5235 gram antipyrine gave 11.52% N.
0.5224 gram antipyrine gave 11.52% N.

Samples were digested as above, and final oxidation was made with permanganate.

Permanganate was added to the hot digested material, which was again heated strongly.

0.5032 gram antipyrine yielded 10.22% N.
0.5038 gram antipyrine yielded 11.48% N.

The flask and its contents were cooled, permanganate was added, and heat was again applied.

0.5030 gram antipyrine yielded 9.90% N.
0.5124 gram antipyrine yielded 10.21% N.

Permanganate was added to the warm liquid, which was not again heated.

0.5201 gram antipyrine yielded 11.61% N.
0.5103 gram antipyrine yielded 11.87% N.

A saturated solution of permanganate in concentrated sulphuric acid was used as recommended by Czeczetka. However, use of a tap-funnel was replaced by a more convenient and less dangerous procedure. The solution in sulphuric acid was poured from a beaker down the side of the flask, then mixed by shaking with the cold solution which had been digested with mercuric oxide.

0.5161 gram antipyrine gave 12.46% N.
0.4888 gram antipyrine gave 12.31% N.
0.4557 gram antipyrine gave 11.97% N.
0.4581 gram antipyrine gave 11.99% N.

Samples were digested with 0.7 gram of crystallized cupric sulphate and 25cc. of a solution of 25 grams of phosphoric anhydride in 100cc. of concentrated sulphuric acid according to Wilfarth.

0.5074 gram antipyrine gave 9.62% N.
0.5037 gram antipyrine gave 9.80% N.

Wilfarth's newer method was also followed. Antipyrine was digested with 0.7 gram of mercuric oxide, 18cc. of concentrated and 12cc. of fuming sulphuric acid.

0.5076 gram antipyrine gave 11.70% N.
0.5029 gram antipyrine gave 11.61% N.

The charge directed by Jodlbauer was used with the addition of 0.2 gram of crystallized cupric sulphate.

0.5259 gram antipyrine gave 10.75% N.
0.5091 gram antipyrine gave 11.16% N.

A sample of antipyrine was permitted to stand over night in contact with 1 gram of salicylic acid and 30cc. of concentrated sulphuric acid; then 5 grams of sodium thiosulphate were added and heat was applied for five minutes. Ten grams of potassium sulphate and 0.2 gram of cupric sulphate were added and the digestion was continued for 5 hours.

0.5010 gram antipyrine yielded 12.11% N.

Two determinations were made by the original method of Arnold with the following charge:

1.1 gram mercuric oxide
0.7 gram crystalline cupric sulphate
2.0 gram phosphoric oxide
1.0 gram sucrose
2.0 gram benzoic acid
30. cc. concentrated sulphuric acid.

0.5216 gram antipyrine yielded 10.12% N.
0.5406 gram antipyrine yielded 10.07% N.

The official Gunning method required 5 hours to produce a clear solution; digestion was continued for an extra hour with this result:

0.5011 gram antipyrine gave 12.26% N.
0.5043 gram antipyrine gave 12.68% N.

The official Gunning method, modified by addition of cupric sulphate, was also tried.

With 0.1049 gram cupric sulphate
0.5026 gram antipyrine gave 11.48% N.
0.2003 gram cupric sulphate
0.5234 gram antipyrine gave 11.24% N. ,

When the method of Arnold and Wedemeyer was tried with a charge of 1 gram each of mercuric oxide and cupric sulphate, 16 grams of potassium sulphate and 30cc. of concentrated sulphuric acid,

0.5650 gram antipyrine gave 10.70% N.
0.5025 gram antipyrine gave 10.43% N.

The bichromate process of Krüger produced the lowest results of the series.

0.2341 gram antipyrine yielded 2.45% N.
0.5053 gram antipyrine yielded 1.57% N.

Dyer's process was applied using 30cc. of concentrated sulphuric acid and substituting 0.7 gram of mercuric oxide for metallic mercury.

0.5097 gram antipyrine yielded 11.69% N.
0.5169 gram antipyrine yielded 11.79% N.

In digesting according to Riviere and Bailhache, 30cc. of concentrated sulphuric acid, 2 grams of sodium pyrophosphate and 0.1 gram of cupric sulphate were used.

0.4706 gram antipyrine yielded 13.47% N.
0.4899 gram antipyrine yielded 13.20% N.

Weighed samples of antipyrine were allowed to stand over night with 5 grams of stannous chloride and 30cc. of concentrated sulphuric acid. Heat was then applied for 10 minutes; 10 grams of potassium sulphate and about 0.1 gram of cupric sulphate were added, and the digestion was continued for 5 hours.

0.4380 gram antipyrine gave 12.62% N.
0.4768 gram antipyrine gave 12.87% N.

An experiment was made using lead peroxide as the oxidizing agent; 0.5104 gram of antipyrine, 8.5 grams of the peroxide and 30cc. of concentrated sulphuric acid were digested for 5 hours. Only 10.20% of nitrogen was obtained.

When the following determinations according to Dakin were made, the potassium persulphate added to each flask was accurately weighed and due allowance was made in the calculation for the nitrogen content of the salt.

0.5256 gram antipyrine gave 12.21% N.
0.5074 gram antipyrine gave 12.33% N.

Sodium peroxide was substituted for the potassium persulphate with this result:

0.5108 gram antipyrine gave 13.25% N.

CONCLUSIONS.

Antipyrine has been digested in sulphuric acid solution with various combinations of the following reagents:

Catalysers—Cupric sulphate, mercuric oxide, platinic chloride.
Oxidizing Agents—Lead dioxide, sodium peroxide, potassium persulphate, potassium dichromate.
Reducing Agents—Sodium thiosulphate, stannous chloride, sucrose, phenol, organic acids.
Compounds which elevate the boiling point of the solution—Phosphoric anhydride, potassium sulphate, sodium pyrophosphate.

In no case has the theoretic per cent. of nitrogen been obtained;

the lowest values were obtained by use of potassium dichromate, the highest results by use of sodium peroxide, or of sodium pyrophosphate and cupric sulphate. The series of results obtained by digestion of antipyrine with mercuric oxide with and without subsequent oxidation by means of potassium permanganate are of interest. When heat was applied after the addition of permanganate, a lower percentage of nitrogen was obtained than when no permanganate was used. On the other hand, when permanganate was added and the digested material was not again heated, a higher percentage of nitrogen was obtained than when the use of permanganate was omitted.

The low values obtained are due either to incomplete oxidation of the antipyrine to ammonia and oxides of carbon or to escape of nitrogen in the elementary state. Since antipyrine-p-sulphonic acid exists, and since antipyrine also possesses the properties of a mono acid base (39), it must be retained in solution by the sulphuric acid and cannot escape from the flask unchanged during the digestion.

The absolute method of Dumas may be applied to antipyrine with success as is shown by the following determination made in the course of this investigation:

0.4319 gram of antipyrine gave 57.3cc. of nitrogen gas, which was measured at 25.6°C. when the pressure of the atmosphere was 761.0 m.m. of mercury. The percentage of nitrogen was 14.73, while the theory calls for 14.89%.

I wish gratefully to acknowledge my indebtedness to Dr. Harry F. Keller, at whose suggestion this thesis was written, for the kindly interest he has taken in my study of chemistry, both as an undergraduate and as an alumnus of the Central High School, and for the inspiration which his lectures have ever been to me.

I also desire to thank Dr. M. E. Pennington for aid and valuable suggestions in the preparation of this paper.

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THE Maschinenbau-Actien-Gesellschaft, Hanover, Germany, has now delivered the 5000th locomotive built at its works, and a summary is published of the work done in the locomotive department since the works were founded, in 1835. Of the 5000 locomotives constructed 1100 were for railroads outside of Germany, of which 241 went to Russia, 115 to Roumania, Japan coming next with 93, and 14 for the Argentine, the remainder being divided between European and Asiatic countries, and six to Chile. The especially interesting remark is made that none of these engines was sent to the United States.—*Iron Age.*

USE OF CROSS-TIES IN 1906.

The Forest Service at Washington estimates that the steam and street railroads of the country used in 1906 for new track and renewals more than 100,000,000 cross-ties. The average price was forty-eight cents. Oak furnished more than 44 per cent., and the Southern pines, which rank second, about one-sixth. Ten per cent. of the ties purchased were treated with preservatives. In the United States, estimating 2800 ties to the mile, there are over 800,000,000 ties in service. Cedar ties last eleven years, spruce ten years, red wood nine years, but these woods are not generally available, and they lack the desired weight and hardness. Of tie timbers in general use—chestnut, white oak, tamarack, spruce and Douglas fir—the average life is but seven years. A treated tie, with equipment to lessen wear, will last fifteen years. It is estimated that to maintain each tie now in track two trees must be growing.

TRANSVAAL GOLD PRODUCTION.

The gold production of the Transvaal in October, while not the highest monthly output on record, approached it very nearly, in spite of the repatriation of a number of Chinese laborers. It was claimed that this loss of men would seriously cripple several of the mines, but such a result is not yet apparent in the returns. This October production brings the total gold yield of the Transvaal for the ten months of this year up to $109,924,238. No considerable changes, either increase or decrease, can be expected in November and December, so that the total for 1907 may be fairly estimated at nearly $133,000,000. This will be an increase of $13,391,000 over the total for 1906; and it will be very nearly one-third of the probable gold production of the world in the present year.—*Eng. and Min. Jour.*

REPORT ON COAL PRODUCTION.

The United States Geological Survey announces the publication of statistics on the production of coal in 1906, in the form of an advance chapter from "Mineral Resources of the United States, Calendar Year 1906."

This report, prepared by E. W. Parker, the statistician in charge, exhibits primarily the details of quantity and value of coal produced in 1906, gives comparisons with previous years, and includes also statements regarding the labor employed, production per man, number of days worked, length of working day, use of mining machines and tonnage produced by them, casualties reported by mine inspectors, and all other matters of interest connected with the mining and marketing of coal. Appended to the report is a list of United States Geological Survey publications relating to coal, comprising about one hundred titles classified by States.

The chapter is now ready for distribution and may be obtained free of charge by applying to the Director, U. S. Geological Survey, Washington, D. C.

Section of Physics and Chemistry.

(Stated meeting held Thursday, April 23d, 1908.)

Standardization Apparatus For Measuring Volts, Amperes and Watts.

By E. F. Northrup, Ph.D.

The developments made in refined electrical standardization apparatus are in answer to a general demand. The desire for accurate electrical measurements is a consequence of the vast developments in manufactured electrical power. The extent and increase in the development of power is indicated by the coal consumption in the United States. In the decade of 1876 to 1885, 848 million tons were consumed; in the decade 1885 to 1895, 1586 million tons, or an increase of 87%, were used, and in the decade ending 1905, the coal consumption was 2833 million tons, or an increase of 78% over the previous decade. The increase in manufactured power, thus indicated, denotes a growing change in man's manner of living not less marked, perhaps, than was brought forth by the advent of fire or of iron. Success whets the appetite and the demand of the age grows to get still more power; moral, money, physical. Of the power manufactured, a continually increasing proportion is converted into and sold as electrical power. This electrical power has become a great commodity of exchange. In the transactions, whereby money power is given for electrical power, it is necessary to measure the barter as well as the exchange, and justice can exist only in proportion as the commodity sold is accurately measured. For every hundred dollars worth of power sold which is measured with an error of one per cent., one party to the transaction has a dollar more and the other party a dollar less than is his rightful due. There is an

ethical demand of the people for justice, and accurate means for measuring electrical power is needed to meet this demand.

All the apparatus actually used in measuring power, which is sold, must finally depend upon concrete standards, made equal to or multiples of the units of definition. The actual calibration of the commercial measuring instruments is accomplished by making use of Standardization Apparatus especially contrived for the purpose.

This apparatus must be reliable in registering quantities that are multiples of the units of definition. The units of definition must be embodied in the form of concrete standards which are maintained accurate through repeated comparisons with fundamental standards under governmental care and certified to by governmental authority. Justice in the sale of electrical power rests on the accuracy of commercial measuring instruments, the accuracy of these rests upon standardization apparatus, and the precision of this rests upon concrete standards certified to by the government.

The National Bureau of Standards at Washington supplies the instrument maker with the means of giving precision to this standardization apparatus, and the decisions of this Bureau have an ethical value not unlike that of the decisions rendered by a superior court of civil law.

Having noted the value and need of precision apparatus for standardizing commercial instruments, I shall discuss the present status of standardization apparatus used in the masurements of volts, amperes, and watts.

Electrical power is composite, being made up of the product volts and the amperes in phase with the volts. When the average power consumed in a given time is multiplied by the time the total amount of energy used is given. In a general way this integrated power corresponds to the total work done by the prime mover and constitutes the basis of charge when the power is sold. Hence, the commercial instrument for determining the proper charge to a customer is the watt-hour meter. But there are both scientific and practical considerations which make it necessary to measure separately the components of power, E. M. F., and current. In the case of direct currents, if either of the factors, volts or amperes, is maintained constant, the total energy is obtained from the integrated product of the two factors multi-

plied by the time and there is, therefore, relatively little use for indicating or integrating direct current wattmeters. With alternating currents, however, the case is different. Here the power is the product of the E. M. F. by the component of current in phase, and as the phase of the current is a shifting and unknown factor, it is necessary to use wattmeters to measure the power which automatically register or indicate the true and not the apparent power. If the wattmeters operate on a dynamometer principle, it is possible, but not convenient, to calibrate them with direct current by measuring the volts and amperes. If, however, they operate on the principle of induction meters they must be calibrated with alternating currents of the frequency with which they are to be used. This calibration is practically effected by comparing them with a standard indicating wattmeter which operates on the dynamometer principle. If the induction wattmeter is an integrating instrument, the calibration may still be made with an indicating standard wattmeter, by maintaining the power, used in the calibration, constant over a known period.

Whether the voltmeters, ammeters, and wattmeters operate on direct or alternating currents, in calibrating them it is always necessary to refer ultimately to direct currents or direct E. M. F.'s. If an induction wattmeter has been calibrated by means of an indicating wattmeter of the dynamometer principle, this instrument, if used as an ultimate standardization instrument, will have had its constant gotten with direct currents or E.M.F.'s.

Any line of standardization apparatus, which is complete for calibrating the instruments used in the commercial manufacture and sale of electrical power, will consist of instruments which will accurately measure D. C. and A. C. volts and amperes, and true watts in alternating current circuits.

Such apparatus, naturally, is classified into direct and alternating current standardization instruments. While the direct current apparatus will not operate on alternating currents, the alternating current apparatus may be used often with direct currents. But, it should be again noted that the constants of all alternating current instruments must be ultimately gotten, when needed, with direct E. M. F.'s or currents, and therefore no laboratory is equipped for making calibrations, which are independent of instrumental constants, unless it is supplied with direct current standardization apparatus.

The developments in electrical standardization apparatus are intimately associated with the names of Kelvin, Siemens and Clark. Kelvin's electrometers, electrostatic voltmeters, and current balances, Siemen's electro-dynamometer and Clark's standard cell employed in potentiometer methods, constituted for years the jury of standard instruments that sat in every well equipped laboratory. The electrostatic instruments of Kelvin could be calibrated with the absolute electrometer, but to convert the indications into electromagnetic measure required a knowledge of the ratio of the units in the electrostatic and electromagnetic systems. Hence, the great importance always attached to this determination. The Kelvin balances were calibrated with direct currents, these currents being measured with voltameters. From the theory of the Kelvin balances it was then assumed that they would serve to give the square root of the mean square value of an alternating current, irrespective of its wave form or frequency. The Siemen's dynamometers, like the balances, were constructed to measure volts, amperes, and watts, and their constants were obtained in the same manner.

The potentiometer, using the standard cell, starts with the E. M. F. of a particular chemical combination as the basis of measurement. The balances and dynamometers calibrated with voltameters start with Faraday's Law of Electro-chemical Equivalents as the basis of measurement. And the dispute is still on as to which is the best foundation to rest upon.

For many years great prominence was given to the tangent galvanometer as a standard instrument for the measurement of direct currents. This instrument, however, is now chiefly used for demonstration purposes, other and more convenient apparatus having taken its place as a standard instrument.

Perhaps there is nothing which more attests the greatness of the early investigators in the budding science of electrical measurement than the comparatively few changes and unimportant developments which have been made in recent years in electrical standardization apparatus for E. M. F., current, and power measurements. Time will not permit me to follow the development of the minor modifications and improvements which our commercial practice, rather than our scientific enquiry, have brought about in historical standardization apparatus. I shall give only in rapid review an outline description of the most modern forms

which this apparatus has taken, and take notice of those features which appear specially worthy of attention.

DIRECT CURRENT STANDARDIZATION APPARATUS.

The practical and the most precise calibration of all forms of direct current instruments is now effected by one method, and by one apparatus, which in its manifold external forms operates on essentially the same principle.

The potentiometer and the potentiometer null method has survived and developed into the simplest and most accurate means for making all direct current standardizations. The success of the method is largely due to the satisfactory precision and permanence to be obtained in standard cells and to the reliability and the simplicity of the apparatus with which the method practically is carried out.

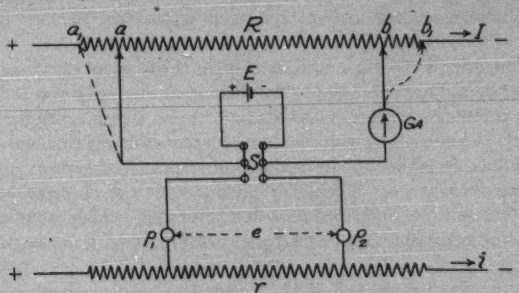


Fig. 1.

The principle of the method in its essential features is indicated in Fig. 1. A source of known E. M. F. and a galvanometer are first thrown in series in a circuit forming a branch to a circuit having uniformly distributed resistance, R. The galvanometer will show no deflection when the current, I, in the circuit is adjusted so that the potential between the points a, b, where the branch circuit is attached, is equal to that of the source of the standard E.M.F. By throwing, with the switch S, a source of unknown E.M.F., into the branch circuit, the value of this E.M.F. is given when the points a, b, are moved into the positions a_1, b_1,

where the galvanometer again gives no deflection provided the current, I, has not changed in the meantime. As R is assumed to be uniformly distributed the unknown E.M.F. is in the same ratio to the known E.M.F as the distance a_1 b_1 is to the distance a, b.

For the potentiometer method to be successful and accurate, means are provided for maintaining the current, I, constant through the resistance, R, during the measurement. The method is made convenient, rapid, and direct reading, by marking the positions taken by the points a_1 and b_1 directly in volts. The source of standard E.M.F. most suitable to use is the Weston Standard Cadmium Cell. This cell has an E.M.F. of 1.01 + volts at temperatures ranging from 10°C. to 25°C.; so that no temperature corrections need be made. The cell will safely deliver a current of .0001 ampere.

The unknown source of E.M.F. may result from the drop produced by a large current flowing through a low resistance. When such is the case, if this resistance, r, between two potential points, p_1, p_2, is known, the value of any current flowing through such resistance is given by the ratio of the measured E.M.F. to the known resistance. Thus, the value of the current flowing through any instrument to be calibrated, which is in series with the resistance over which the potential drop is measured, is directly determined.

Or a direct source of E.M.F. may be obtained from storage cells and be many times as great as that of the standard cell. When such is the case, a so-called volt box is employed. By this device, a known decimal fraction of the total voltage, which does not exceed the E.M.F. of the standard cell, is carried to the potentiometer terminals and measured. D. C. Voltmeters are thus calibrated.

Or the source of unknown E.M.F. may be the feeble E.M.F. of thermo-couples, much used now in temperature determinations. When a thermo-couple is used with a galvanometer in series with it to measure its E.M.F., the E.M.F. is only indirectly measured, the galvanometer directly measuring the current developed by the thermo-couple. If the resistance of the entire circuit can be known and maintained constant, then the galvanometer can be made to measure the E.M.F. developed. When the potentiometer is used for measuring thermo-couple E.M.F.'s, these are given di-

rectly and are determined independently of the resistance in series with the thermo-couple, because at the moment of balance no current flows in the thermo-couple circuit. High precision is thereby given to a measurement that by other methods is but moderately accurate.

It will be noted that in all potentiometer null methods no instrumental constants enter into a measurement. The determinations, whether of E.M.F. or current are given in the form of direct comparison with standard E.M.F.'s and resistances. The possible precision and permanence of concrete standards of these two quantities is very great, accuracies of a 1/25% or better being entirely practicable in commercial practice.

The potentiometer adds to its high precision a very extended range. An instrument for commercial use, when supplied with suitable current standards and volt boxes, will measure currents from less than .00001 of an ampere to 6000 amperes by practically infinitesimal steps and E.M.F. from .0001 volt to 1500 volts in like manner, or much higher voltages, if resistances in volt boxes are constructed for the purpose.

On account of the fluctuating character of commercial voltages it is not always easy, in measuring these voltages, especially when applied to standard lamps in photometric work, to manipulate the sliding contacts of a potentiometer, and secure the exact balance of the galvanometer, required by the null method.

This consideration has led to the development of a type of potentiometer by Dr. H. B. Brooks, of the National Bureau of Standards, which is intermediate between a deflection and balance type of instrument.

The essential principle of this admirable instrument is that the bulk of the unknown voltage is measured by the potentiometer method and the small remaining departures from the exact value are indicated by a delicate millivoltmeter of the Weston type. Reference to a full description of this instrument may be found in the Bulletin of the Bureau of Standards, Vol. 4, No. 2, for January, 1908, p. 275.

The variety of forms which have been given the potentiometer by physicists and by instrument makers precludes even a cursory mention of the best of them. Broadly considered they may be grouped into high and low resistance potentiometers, according as the potentiometer circuit is made up of groups of resistance

coils without an extended slide wire and having a total resistance of several hundreds or thousands of ohms, or is made up of a few resistance coils of comparatively low resistance to give the coarse steps, and an extended slide wire to give the fine or infinitesimal steps in the adjustment of a voltage balance. The mechanical difficulties in the construction of the low resistance instrument are perhaps greater than in the high resistance type, but these difficulties having been met, the practical working is simple and the theoretical sensibility is greater.

The potentiometer shown in Fig. 2 is of the low resistance type. It has fifteen coils of five ohms each, giving fifteen steps of 1/10th volt each, and a circularly arranged stationary slide wire about

Fig. 2.

210 inches long and making eleven turns around a marble cylinder. Ten of these turns are equal to the resistance of one coil.

A travelling sliding contact moves over this wire and a scale reads directly in steps of .0001 volt. By means of a shunting device on the potentiometer wire each step given by the coils is made to equal .01 volt and the smallest divisions upon the scale, indicating the lowest steps, is made to equal .00001 volt. Means are also provided for quickly checking the current through the potentiometer circuit without losing or changing the setting obtained for a balance when measuring the unknown E.M.F. This type of instrument with its necessary accessories, consisting of a rheostat to regulate the current, current shunts, and volt boxes, storage cells

to furnish a steady current, and standard cadmium cell, makes an outfit which will cover every possible case of the calibration of commercial direct current instruments used to measure volts, current, and power.

The deflection type of potentiometer as realized in its commercial form and designed by Dr. Brooke, is illustrated in Fig. 3. This instrument covers in an exceptionally convenient manner the rapid voltage measurements that must be made in lamp photometry. It is likewise serviceable for all voltage measurements of moderate or high E.M.F. The measurements are made by setting the dials until the unknown E.M.F. is approximately balanced. The exact E.M.F. is then given at any instant by adding to or subtracting from the value of the E.M.F., indicated by the positions of the dials, the small E.M.F. indicated by the deflection of the millivoltmeter.

There are many foreign makes of potentiometers of deservedly high popularity, but in recent years this instrument has received a careful study and refined development in America. This development has been made in answer to the demand of capital invested in commercial measuring instruments which must be maintained in accurate calibration for correctly measuring the vast quantities of electrical power manufactured and sold. Where these instruments operate upon direct currents they can all be checked or calibrated with a potentiometer by which their indications are referred directly to standards of E.M.F. and resistance, which standards in turn may bear National Bureau certificates. Thus the possible standardization of all direct current commercial apparatus is on a most satisfactory basis, and it only requires legislative action and careful watching to insure that determinations are made to any required degree of commercial accuracy of all direct current power which is sold.

ALTERNATING CURRENT STANDARDIZATION APPARATUS.

Since the power in an alternating current circuit depends not only upon the volts and amperes in this circuit but also upon the phase relations between these two quantities, it is necessary, in standardizing an instrument which is to measure power, to be able to measure the volts and amperes and the phase relations between them; or to provide a standardizing instrument which meas-

STD CELL
E.M.F.
RECHARGE
THE LESLIE R NORTHRUP CO
PHILADELPHIA

Fig. 3.

ures true power independently of phase relations. As the phase relation can be determined practically only in the rare case of pure sine wave currents, the latter course is the practical one to adopt. A full line of alternating current standardization apparatus will consist then of instruments which will measure with high precision volts, amperes, and true watts. The range of measurements which must be provided for with these instruments is greater than in the case of direct current instruments. By means of potential and current transformers, alternating current power is furnished in the form of small currents and high pressures and large currents and low pressures. To cover the cases of actual practice instruments are required which will measure pressures up to tens of thousands of volts and currents to several thousands of amperes. On the other hand comparatively small E.M.F.'s and currents often need to be measured. In calibrating wattmeters of very large capacity it is generally necessary to be able to do this without actually developing electrical power, which is more than a small fraction of the power which the wattmeter under calibration will register. While the principles of accurate measurement of electrical power laid down by the early investigators, are sufficient to cover all modern requirements, the apparatus designed by them is inadequate for handling the extensive ranges of measurements now required to be made.

Thus Kelvin balances that will register 1000 amperes, which must pass through the copper ligaments supporting the swinging coils, become elaborate and costly instruments. It is not practical to construct a Siemen's current dynamometer to carry much over 500 amperes, and even such an instrument is costly to build. Furthermore, the inductive effects of large alternating currents are so great that grave errors, often too subtle to detect, are introduced by eddy currents in metal parts and in the coils of large-current instruments. To avoid both the cost and the danger of error in the use of heavy current standardization instruments, it is customary to resort to both potential and current transformation by means of iron-cored transformers to bring the volts and amperes within the ranges of the instruments of small or moderate capacity that are used and practical to build when constructed according to customary patterns. But this practice at once introduces into the measurements a new set of constants, namely,—the ratios of transformation of the transformers em-

ployed. If these ratios could be obtained accurately by calculation, and could be relied upon to remain constant with currents of different frequencies and wave forms, and if they were the same for 10% and 100% of full transformer loads, and if the iron in the transformers were not subject to a slow aging, and if the phase relations between the currents and the pressures could be determined and remained fixed, then, if all these demands of an accurate method could be assured, there would be no necessity of standardization apparatus of capacities exceeding 110 volts and five amperes.

Experimental investigations (See discussion by L. T. Robinson on "The Current Transformer" Proceedings of A. I. E. E., Vol. XXV, p. 727, September 28, 1906), however, show that for standardization purposes, transformers will not yield results that are satisfactory for the purpose, unless all their constants are determined experimentally under the conditions in which they are to be used. This determination necessitates, of course, standardization apparatus of large capacity.

The real problem then introduced by the manufacture and sale of large quantities of alternating current electrical power, is how to design and construct standard alternating current instruments to measure volts, amperes and watts, which shall cover, in the most efficient manner in regard to cost, a great range of measurements with high precision. Direct current measurements are now referred by the potentiometer method, directly to standards of E.M.F. and resistance, without the intervention of instrumental constants, which depend for their constancy upon the properties of materials, such as the elasticity of springs and the magnetization of steel. It is equally desirable to develop alternating current standardization instruments to operate upon principles that make them independent of instrumental constants; and for volts and current measurements this has been accomplished in an entirely satisfactory manner in the ways to be described.

The direct measurement of the square root of the mean square value of alternating current volts is simpler and easier than the same measurement of alternating currents of large value. The measurement resolves itself into two methods. In one the potential is measured by an electrometer calibrated with an absolute electrometer and converted into volts by the now accurately known value of v, the ratio of the electromagnetic to the electrostatic unit. In

the other the potential difference is determined by measuring the very small current which flows through a high and non-inductive ohmic resistance. This latter method is advocated as being probably the more accurate and better adapted to commercial requirements. The precision of the method depends upon winding a high ohmic resistance which is nearly free from inductance and capacity, so that reliance may be placed upon the practical coincidence in phase of the current through the resistance and the potential at its terminals. This result is easily gotten in the form of resistance here shown.

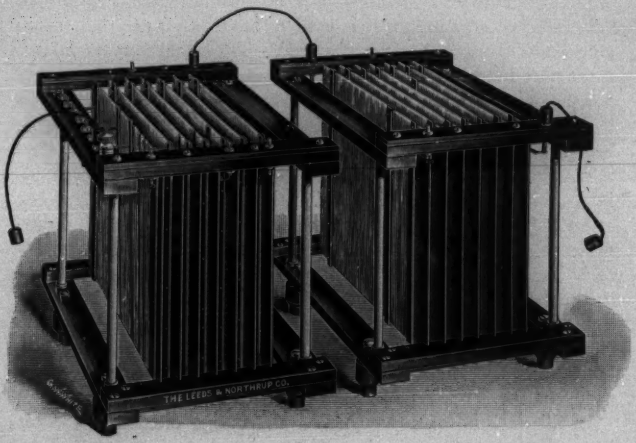


Fig. 4.

The wire used is manganin insulated with black enamel about .0002" in thickness. This wire has a temperature coefficient not exceeding .00002 per degree Centigrade, and a resistance about twenty-eight times that of copper. The wire is wound with turns close together upon sheets of micanite 1/16" thick. These sheets will safely dissipate ¼ watt per square inch of winding. On account of the high specific resistance of the wire and the manner of winding, these resistance cards have an exceedingly small capacity and inductance which may be entirely neglected in any alternating current measurements made for standardization purposes. The card units may be joined in series and mounted in

highly insulated frames and so give resistances to which tens of thousands of volts may be safely applied. The current flowing through them may be calculated on the basis of Ohm's Law. A measurement of this current at once gives the square root of the mean square potential at the terminals of any known section of this resistance. The resistance value is ordinarily adjusted so that with the potential applied the current will not exceed one-tenth of an ampere.

This small alternating current may be measured by a deflection instrument of the electro-dynamometer type or by a null method. If a dynamometer instrument is used this instrument should be calibrated shortly before it is used to have assurance that its instrumental constant has not changed. The dynamometer instrument may be calibrated on direct currents using a potentiometer for the purpose. As the swinging system of portable instruments of this type has but one coil the influence of the earth's field must be eliminated when making the calibration by reversing the current used in the calibration and taking the mean of the two readings as the true value. The calibration should be made over the entire portion of the scale used in the alternating current measurement, as the deflections cannot be relied upon to follow accurately the square law. A better type of electro-dynamometer for the purpose is one in which the swinging system consists of two light coils that make in reference to the earth's field an estatic combination. Such an instrument will then read the same on both direct and alternating currents, and it is unnecessary to reverse the former when calibrating the instrument.

In this method of measuring an alternating current voltage it is to be noted that a deflection of a moving system is read and reliance is placed upon the accuracy of the calibration of a scale and the maintenance of the constancy of the indications of the instrument. The directness and the simplicity of the potentiometer method employed with direct current calibration, therefore, is lacking. The accuracies are limited to a fifth or at best a tenth of a per cent. Instruments of the Siemen's dynamometer type and hot wire instruments might be substituted for the deflection electro-dynamometer, but both must be calibrated, and there is no gain in simplicity or precision.

It is highly desirable to be able to measure alternating voltages and currents by a null method, which at once eliminates all instru-

mental constants and which will place alternating current measurements upon the same basis as the potentiometer method places direct current measurements, namely, the effective value of an alternating voltage should be compared directly with the E.M.F. of a standard cell and, as is in the potentiometer method, the quantities measured should be given directly in terms of the value of a standard cell and values of resistances. In other words, to place the measurement of alternating current voltages and amperes upon the same satisfactory basis as the measurement of direct current voltages and amperes, a potentiometer method, employing in effect an alternating current potentiometer, should be used. To accomplish this end there has been designed certain null methods using an instrument which has been designated, the alternating current-direct current comparator. This instrument measures without the intervention of instrumental constants or quantities other than resistances and a standard cell, alternating current volts and amperes, and, where power can be expended in a non-inductive load, alternating current watts. As noted above, the measurement of alternating current voltages resolves itself into the accurate measurement of a small alternating current which flows through a highly non-inductive resistance. We may, therefore, introduce here a brief description of the A. C.-D. C. Comparator, and then explain the unimportant modifications in the method and apparatus to use the comparator for the direct measurement of large alternating currents up to a thousand or more amperes.

The complete instrument, together with a shunt, employed in the manner to be described for measuring large currents, is illustrated in Figure 5.

The differential system or wire holder is illustrated in Fig. 6. In its essentials the apparatus is an exceedingly sensitive instrument for detecting differences between two small currents and showing when they are equal. Its action is the same whether the currents be direct or alternating, consequently it can be used to show equality between small direct and alternating currents.

Referring to Fig. 7, A B and C D (also shown in Fig. 8), are two small wires of equal length, diameter and resistance, stretched as shown, about 5/32″ apart and pulled back at their middle point by a cross-piece resting on each wire. A spring attached to this cross-piece keeps a constant tension on the two wires. A

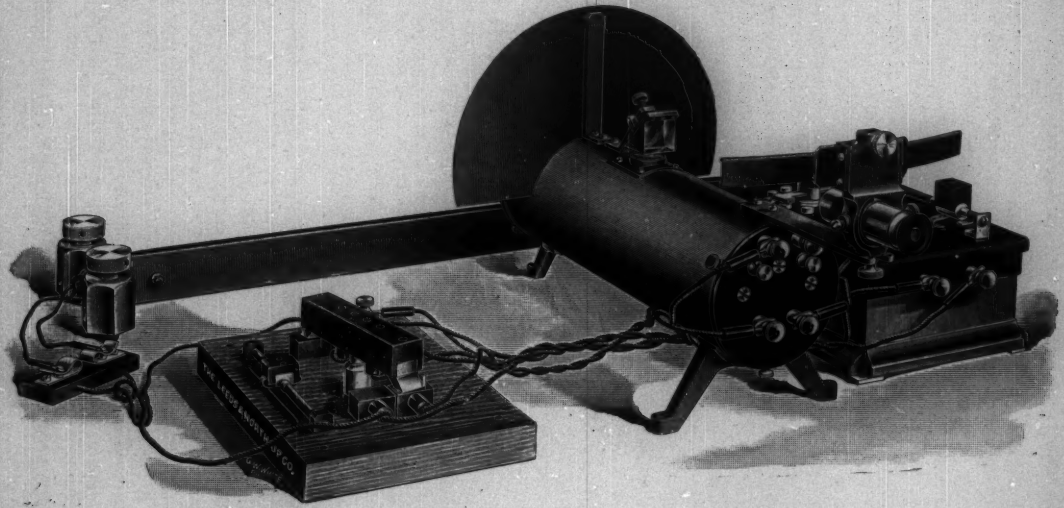


Fig. 5.

mirror is mounted on the cross-piece. Fig. 8, which is a cross section across the wires, and the cross-piece makes clear the construction of this part of the apparatus. It will be evident that if one wire elongates more than the other, the mirror will tilt, and a very slight tilting can be observed by the telescope and scale, in Fig. 6. As both wires will be influenced in the same way by external temperature changes, the apparatus will not be influenced by them. Equal currents flowing through both wires will cause

Fig. 6.

Fig. 7.

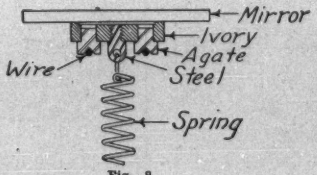


Fig. 8.

equal elongation and no deflection; but a slight difference in the current in the two will cause unequal elongation, due to heating, and a deflection.

The diagram, Fig. 9, shows how A. C.-D.C. Comparator may be used to measure the small current through the non-inductive high resistance, R_v, and, consequently, the voltage between A. C. mains.

S is a double-throw switch. When this switch is on "check," the two wires are in series with each other and are both traversed

by the current which can flow from the line through the non-inductive high resistance R_v. Under these circumstances, the comparator must be adjusted so as to show no deflection. With the switch at "test," exactly the same current will flow through the wire A B, as r^1, has the same resistance as C D and replaces it. By adjustment of rheostat r, the same current is made to flow through C D as will be shown by a balance. This current is read by an accurately standardized D. C. instrument Am, or better, by a potentiometer, which eliminates all instrumental constants. Calling this C, the E.M.F. across the A. C. Voltmeter will be $V = C R_v$.

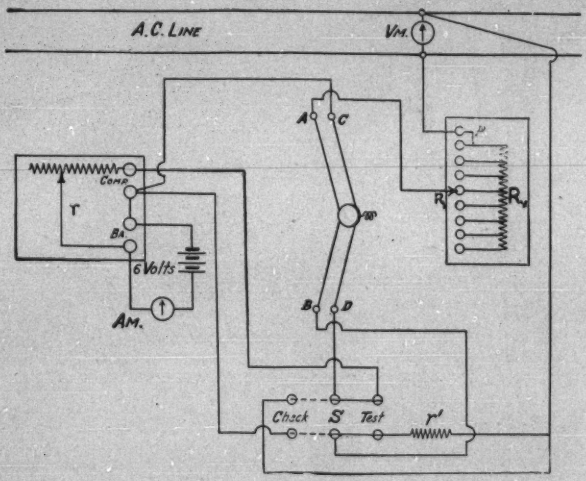


Fig. 9.

When it is required to measure larger alternating currents than can be carried by the wires of the comparator this may be accomplished by employing non-inductive shunts. These shunts must be designed to be highly non-inductive and independent of temperature changes. Both of these results are secured by building the shunts of sheet manganin—an alloy which has practically a zero temperature coefficient—and arranging the material in a non-inductive form as is illustrated in the shunt shown back of the in-

strument, Fig. 5. The simplified diagram, Fig. 10, shows the essentials of the theory of measuring large currents with the A. C.-D. C. Comparator.

A B and C D represent the two wires of the instrument; R is the non-inductive resistance through which flows the A. C. current to be measured; f^1 and h^1 are potential points on it, the resistance between which is accurately known. The lead resistances, ef and gh, are made equal to e^1f^1 and g^1h^1. S S are the two parts of a switch (separated in the diagram, but not in practice) by means of which the terminals of the wire C D may be connected either to e^1 and g^1 or e and g. V is an accurate D. C. voltmeter, or better, a potentiometer; r is a regulating rheostat and m a battery.

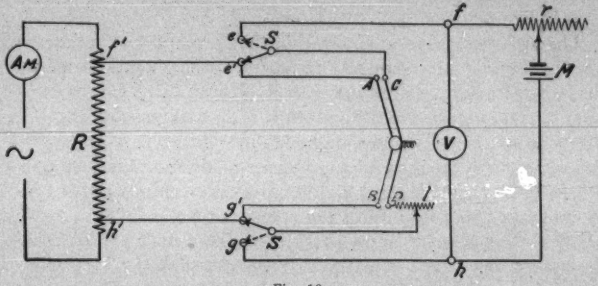


Fig. 10.

In making a measurement, the switch S is thrown so as to connect the two wires in parallel, then by means of the small rheostat l an adjustment is made until the comparator gives no deflection when the current, which is to be measured, flows through R. This adjustment of rheostat l may be neglected in all cases except when comparatively high resistance shunts are used. The switch is next moved so as to connect C D to the direct current side and r regulated until there is again no deflection. From the symmetry of the construction, it will be evident that the direct E.M.F. read on the instrument V will be the same as that across the points f^1 and h^1. Calling this v, the current through the Ammeter Am will be $\frac{V}{R}$ + the current which flows through the wire A B. The small portion of the current which flows through A B varies with v, but is determined for each instrument for all values

of v and may be expressed in the form of a curve called the function v curve, F (v). The complete formula for the current is then

$$C = \frac{V}{R} + F(v).$$

The resistances R are so chosen and the apparatus is so designed that for all measurements of current above six amperes v. varies between the limits .2 and .6 volt, consequently, for the D. C. side, a single battery, rheostat and standard instrument for measuring up to .7 volt, is all that is necessary for the measurement of all ranges of alternating current above six amperes.

By means of slight modifications in the apparatus and shunts, currents from six amperes down to 1/20th ampere may be measured in like manner.

The above description shows that the A. C.-D. C. Comparator may be used as a companion instrument to the potentiometer and thus all voltages and currents both D. C. and A. C. can be measured directly in terms of a standard E.M.F. and resistances. The precision of the A. C. measurements may be made equally high throughout the range of measurements made if a sufficient number of high resistance units and low resistance shunts are at hand to maintain the sensibility of the comparator about the same, regardless of the volts or amperes being measured. Experience shows that this result is practically accomplished if a new resistance value and new low resistance shunt be used each time the voltage or current being measured is doubled in value.

For obtaining sufficient sensibility in large current measurements it is necessary to have the potential drop over the shunt equal to not less than .2 volt. Hence, a shunt to use in measuring 1000 amperes would have to dissipate at least 200 watts. This means that for large current values the shunts must have a large size and heavy construction which makes their cost considerable when 500 or 1000 amperes are exceeded. Outside of this consideration alternating current measurements of volts and amperes for calibration purposes are on nearly as satisfactory a basis as direct current measurements; for the directness of the A. C. measurements is nearly equal to that of the D. C. measurements, while the precision of the measurements is easily made equal to 1/10th per cent. or better.

To cover, however, the present commercial requirements where

the alternating current is used in electric furnaces, in electric welding and in power stations of large output, it is often desirable to be able to measure currents considerably exceeding 1000 amperes. In practice, these large currents would be measured with the aid of a series transformer. The ratio of the transformer would be computed and its small secondary current would be measured by an alternating current ammeter which could be accurately checked by any of the well known methods. The large primary current would then become known as accurately as the calculated ratio of transformation of the series transformer. A true and accurate value of the ratio of a series transformer cannot, however, be obtained by computation. The ratio should be obtained experimentally, under the conditions of frequency, wave form and load, in which the transformer is to be used to get an accurate determination of the heavy primary current from a precise measurement of the small secondary current. There is, therefore, need of a standardization instrument, of not excessive cost, which can be inserted directly in an alternating current circuit carrying any current over 1000 amperes, and which will measure this current with the same precision as small alternating currents are measured. The problem of measuring a very large alternating current with precision is a difficult one from a technical standpoint and has always heretofore involved the use of very expensive apparatus. The method of the A. C.-D. C., Comparator would make the measurement accurately, but the expense for the shunt would be large. To measure 10,000 amperes would require a shunt that would dissipate 2000 watts, and if this were air cooled in still air, it would have to have a superficial area of 28 square feet. The measurement might, however, be made practicable by using tubular shunts of manganin cooled with water circulating through them. A Kelvin balance for such a great current has been constructed and used in England, but this is, of course, a very costly piece of apparatus and was specially constructed under Lord Kelvin's supervision. The measurement has been made in Germany by passing the alternating current to be measured through a sheet of platinum until it became incandescent. The current through the filament of an incandescent lamp is varied until the filament when seen against the incandescent platinum surface disappears. This lamp current then is held constant while a measured direct current is passed through

the platinum sheet until the lamp filament again disappears. The known direct current and the alternating current are then taken to be equal. But methods such as the above, involving, as they do, elaborate apparatus and direct currents of like magnitude with the alternating currents with which to obtain the constants of the apparatus, are not likely to be used outside of laboratories having a governmental equipment.

By the development of a new method an apparatus has now been designed, known as the Mercury Ammeter, which at relatively slight expense will measure alternating currents with precision of any large magnitude. Barring the extra cost of construction the massive copper terminals needed for conveying heavy alternating currents into the instrument, the expense of construction is approximately the same whether the current to be measured is 1000 or 50,000 amperes. The principles upon which the Mercury Ammeter is based were given in a paper by the writer entitled, "Some Newly Observed Manifestations of Forces in the Interior of an Electric Conductor," Physical Review, June, 1907. At that time a rude instrument was shown which would roughly measure about 600 amperes. Since then experiments have been conducted and instruments constructed with the object of bringing the apparatus and method into a practical form. Success has been secured, and there is shown in Fig. 11 a mercury ammeter suitable for measuring 2000 ammeters alternating current.

The figure is a cut from a cross-sectional drawing that shows the manner in which the instrument is constructed.

The action of the instrument depends upon the essential principle that when a current, direct or alternating, passes through a conductor, there is set up in the conductor an attraction toward its axis of all the imaginary elemental filaments of the conductor. This attraction, when the conductor is a liquid conductor suitably confined in an insulating tubular space, results in a difference of hydrostatic pressure between the axis and the circumference of the conductor. This difference in pressure in a conductor of circular cross-section is numerically equal to the square of the current strength and inversely equal to the cross-sectional area of the conductor. If the conductor is made up of two or more liquid portions in circuit with solid portions, the differences in pressure set up by the passage of the current in the liquid portions may be

added, like electromotive forces, in series and the resultant pressure difference utilized to raise a column of liquid. This raised liquid column may be used to directly measure the value of the current, or the motion of the raising column can be communicated to any style of pointer moving over a scale or dial.

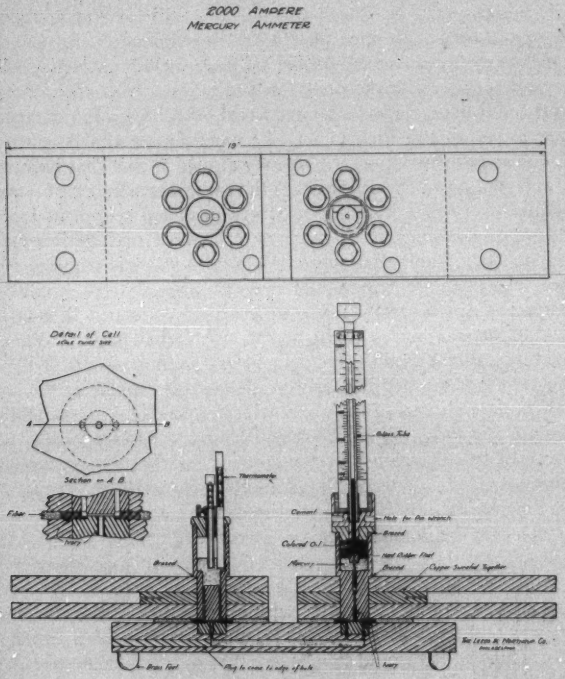


Fig. 11.

The liquid found to be best adapted to use in the construction is mercury. The height to which the mercury column will rise with a given current may be magnified for convenience of observation, but not for accuracy, by causing the pressure to be transferred to a column of colored water. Further description

of the mechanical features of the apparatus is made unnecessary in view of the two illustrations given.

It has only been found necessary to use two mercury pockets or cells and to make these but 1/64th of an inch in their axial dimension. On account of their short length and the proximity of massive copper blocks to rapidly conduct away the heat great current densities may be passed through the cells. In fact 20,000 amperes to the square inch gave a rise in temperature in the cell as measured by a thermo-couple of only 16°C. Mercury has sixty times the resistance of copper, and hence, if this latter metal were to replace the mercury current densities of 1,200,000 amperes per square inch under like conditions could be passed through the short conductor. It may also be shown that keeping the axial length of the cells always the same, the number of watts required to raise a column of water a given height is independent of the number of mercury cells used and the current passing. It is found that approximately 1.4 watts is required for every inch rise of water. Hence, as an ammeter properly constructed can be easily made to dissipate 35 watts, it can be made to give a scale, using water, 25 inches high. When, however, water is used the instrument has a temperature error of $\frac{1}{2}$ per cent. per ten degrees Centigrade, as this represents the increase in the lightness of the water which expends one part in four thousand for every degree Centigrade. For precision work the error may be calculated and allowed for, as the temperature is easily measured. If water is not used the rise in the mercury column may be directly observed with a cathetometer or microscope, in which case the possible precision is very high. The indications are absolutely the same with direct and alternating currents and strictly follow the square law. It is proposed to carefully construct a large mercury ammeter with all its dimensions carefully measured and to employ it in the absolute determination of current. This method would supplement that of the absolute electrodynamometer giving the value of the current as the square root of the area of one cell, the force of gravity times the height to which the mercury raises, times the specific gravity of the mercury and inversely as the square root of the number of cells joined in series.

The mercury ammeter may, if desired, have its constants obtained at one point on the scale by passing a large known storage

battery current through it; the remainder of the scale may then be laid off by calculation and the instrument is then adapted to give precise measurements of large alternating currents. By inserting this instrument in series with the primary of a series transformer of large capacity to measure the primary current and by measuring at the same time the secondary current with the A. C.-D. C. Comparator, or any instrument which has been checked by it, the ratio becomes accurately and experimentally determined. The series transformer with its constants determined in this manner becomes then a truly valuable adjunct in the measurement of large alternating currents. It only remains to determine the phase relations existing between the primary and secondary currents of the transformer to make of it a precision piece of apparatus. The useful lower range of the Mercury Ammeter has not yet been fully determined, but though a 500 ampere instrument is easy to construct, there would be little demand for instruments of similar capacity, as below this precise null methods are available.

Before leaving the subject of the accurate measurement of alternating currents for standardization purposes, mention should be made of the method in which a sensitive electro-dynamometer, with a low resistance astatic moving system, is employed with non-inductive shunts to carry the main current being measured. This method has had a full development at the National Bureau of Standards in the hands of Dr. E. B. Rosa, and is fully described in the Bulletin of the Bureau of Standards, Vol. III, No. 1, p. 43. The constant of the dynamometer is obtained with direct currents under working conditions and the circuits are so arranged that assurance is furnished that the constant is the same for alternating as for direct currents. Substantially the same method of measuring alternating volts, amperes, and watts is embodied in an apparatus originally designed by the late Prof. Henry A. Rowland, of Johns Hopkins University. The dynamometer part of this apparatus is shown in Fig. 12, and known as the Rowland Dynamometer and Shunt Box, and consists essentially of an assemblage of shunts and a wall form of deflection electro-dynamometer with attached telescope and scale to observe deflections. The dynamometer is now made with an astatic moving system which makes it read the same on direct and alternating currents. Its useful range, when used with shunts, is from .001 to 50 amperes. Switches placed upon top of the box

containing the shunts and also non-inductive high resistances serve to quickly give the necessary connections for a large variety of measurements of volts, amperes, and watts. In Rowland's original papers, namely, "The Physical Papers of Henry Augustus Rowland," The Johns Hopkins Press, Baltimore, 1902: "Electrical Measurement by Alternating Currents," by H. A. Rowland, p. 294; and "Electrical Measurements," by H. A. Rowland and T. D. Penniman, p. 314; many methods are given for measuring with this apparatus other electrical quantities, as inductances, capacities, electrolytic resistances, etc. This apparatus and methods of using it are very useful in a laboratory for mak-

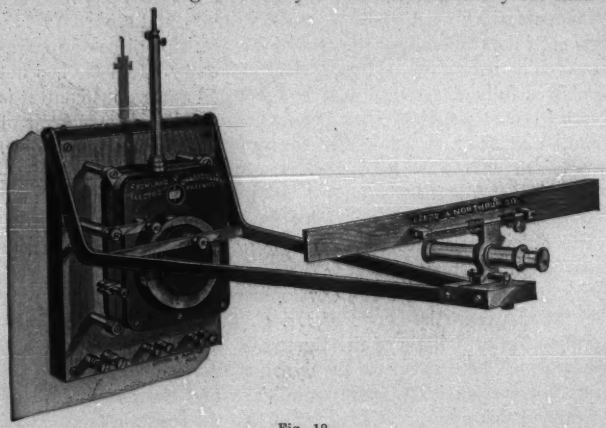


Fig. 12.

ing an extended range and variety of alternating current measurements, but the apparatus and methods are not so well adapted to standardization purposes as the null methods, which are independent of any instrumental constant. By suspending the electrodynamometer system with a very light suspension the instrument may be made sufficiently sensitive to measure with good accuracy the small E.M.F.'s and currents used in telephone practice. In this manner the instrument may be used as a standardization instrument for alternating currents in the range from .0003 to .1 ampere, it being necessary of course to obtain the instrumental constant with direct currents.

STANDARDIZATION WATTMETER.

In the manufacture and sale of alternating current electrical power, the instruments used for measuring this power commercially must be calibrated, and a line of standardization apparatus would be very incomplete, and without the most essential instrument of all, if it did not contain, in addition to apparatus for the precise measurement of volts and amperes, a standard wattmeter capable of registering alternating current power directly and accurately. As has been shown, E.M.F.'s and currents, both direct and alternating, may be measured directly, without introducing any instrumental constants, in terms of the values of resistances and the E.M.F. of the standard cadmium cell. In the direct measurement of alternating current power it is still necessary to bring into the measurements the value of an instrumental constant when the power being measured, as is generally the case, has a power factor less than unity. For this reason, the standard wattmeter, operating upon the electro-dynamometer principle, the only instrument yet devised for the accurate measurement of power of non-unity power factor, requires both for its design and application the most careful consideration. The design and use of the instrument, and the manner of obtaining its constants must be such, that a satisfactory reliance may be placed upon the instrument to give the same indications when used with direct and alternating currents, regardless of wave form and frequency. To give a description of the many features in the design of a standard wattmeter that merit attention would be far beyond the scope of this paper. We shall only show here, Fig. 13, an illustration of a standard wattmeter of 25 to 300 amperes capacity, which has been designed with great care to embody all the features which are needed to make of it a truly standard piece of apparatus which can be relied upon to use in the precise calibration of any form of commercial indicating or integrating wattmeter on alternating current and non-unity power factor circuits.

The most essential features in the construction are the following:

The Siemen's electro-dynamometer principle of construction has been adopted in which the suspended or movable system maintains at the moment of balance a fixed position in the magnetic field, due to the stationary coils. The magnetic forces are bal-

anced by turning a torsion head which twists a suitable suspension sustaining the movable system. The setting of the torsion head is read with a Vernier upon a scale ruled on a hard rubber disc six inches in diameter. The zero position of the moving system is given by a long pointer which has a limited motion over a short scale ruled on ivory and is read from the top of the case by looking through a tubular eye-piece which contains a magnifying lens. The fixed coils of the apparatus are wound to give a field that is strong and nearly uniform in the space in which the sus-

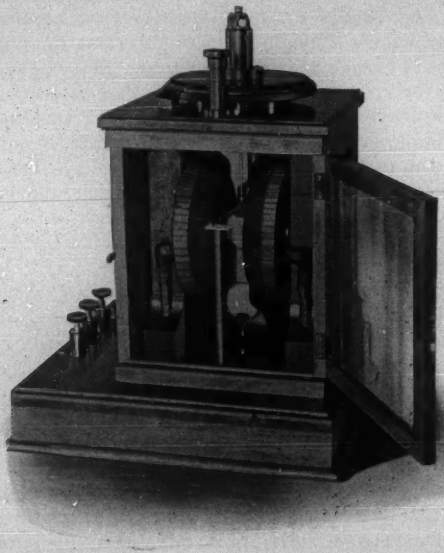


Fig. 13.

pended system swings. The Helmholtz arrangement is used in which the distance between the medial planes of the two coils of the pair is made nearly equal to the mean radius of one of them. The coils themselves are wound with a large number of silk insulated wires in parallel which effectually avoids eddy currents in the coils themselves. By bringing out connections to three binding posts either 10 or 20 turns total may be put in circuit, but

in no case do the alternating currents divide to flow in parallel circuits. A certain foreign designer has been tempted to design a watt-dynamometer, which is widely known, to have many different constants and current ranges in small steps by joining the fixed coils in various parallel combinations. This the writer considers to be very unsafe practice. For, after one set of coils has been in use, they will be at a higher temperature and resistance than the unused coils, and the current will not divide in the same manner as when these coils are first used; besides, alternating currents would be likely to produce currents that would circulate in the closed circuits in a different manner at different times, thus varying in an unknown and unsuspected manner the instrumental constants.

The swinging system of the instrument here illustrated consists of two very light coils which form in respect to the earth's field, and alternating currents in conductors outside of the instrument

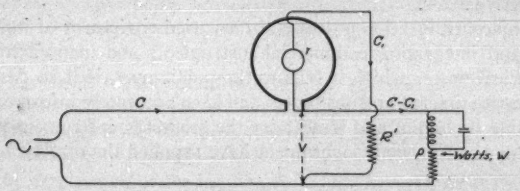


Fig. 14.

case, a perfect astatic combination. This suspended system carries a maximum current of only .04 amperes and may be used for moderate or high voltages with outside non-inductive card resistances of small cost. The system is suspended by a long spiral spring which both sustains its weight and serves by turning the torsion head to oppose the electro-magnetic forces.

The system is made just aperiodic by means of a small mica vane moving in a small hard rubber box filled with a thin oil.

The entire case and supporting frames are of insulating material either mahogany wood or hard rubber. Glass doors make the parts visible and easy to handle and adjust.

In using this instrument to measure power it would be connected into the circuit in the manner shown in Fig. 14.

If it were required to prove beyond any question of doubt that

this form of watt-dynamometer has the same constant for alternating as for direct currents this might be done by measuring with it the watts expended in a perfectly non-inductive load. The watts would then be equal to the square of the current by the non-inductive resistance of the load. The resistance is easily measured and the current may be measured with great precision by the A. C.-D. C. Comparator.

We are thus led to the conclusion that the science of electrical standardization measurements has advanced to a point where all commercial E.M.F.'s and currents, direct and alternating, may be measured with precision directly in terms of resistances and a standard cell, and that alternating current power may be measured accurately but through the medium of an instrumental constant. This constant, however, may be gotten with direct currents measured with a potentiometer, and this may be verified by the alternating current potentiometer or comparator on non-inductive loads.

Any central station possessed of a varied equipment of indicating and integrating commercial instruments and manufacturing electrical power which it sells to the public may, if it so desires, do justice to itself and customers and keep accurately informed regarding its output and losses; for the scientists, instrument makers and the National Government have supplied the direct and inexpensive means.

TIMBER OWNERS ORGANIZE TO FIGHT FIRE.

One of the most important economic movements of the day about which the general public has yet learned little is the concerted action of owners of timber in different parts of the country in organizing associations to protect their holdings from fire. In the Pacific Northwest, the Washington Forest Fire Association has just elected officers at Seattle and begun work for the year with 3,000,000 acres under its care. The plans include a system of patrol by rangers resembling the work done by the United States Forest Service in guarding against and extinguishing fires.

Organizations of similar kind and for a like purpose are at work in Oregon and Idaho. In the latter State, a portion of the expense is borne by taxation and paid from the State Treasury. A Western railroad company, which holds large tracts of timber, has taken steps to guard its property from fire, and during the short time that its plans have been in operation it has met with most encouraging success.

Similar work is being done on the other side of the continent. Forest owners in Maine have gone to work in the same systematic way to control the forests' great enemy, fire. Like organizations are found in other parts of the country, showing how fully it is now realized that protection against fire is of the greatest importance.

(Read at the stated meeting Thursday, January 2d, 1908.)

Cement—Its Use and Abuse.

By Robert W. Lesley, Associate Am. Soc. C. E.

In a recent Government publication, Mr. Gifford Pinchot, Chief of the Forestry Bureau of the Agricultural Department, makes the following statement:

> "In twenty years we may be in the midst of a lumber famine. We have enough standing and matured timber to last that long. With the timber that is growing the famine may be put off five years. One-fifth of the standing timber is embraced in forest reserves. The rest of it belongs to private ownership. We must be economical in the use of lumber."

This fact is corroborated in other Government publications, in speeches by Government officials and in the publications in trade papers representing the lumber industry, the period of time now being reduced to fourteen years. The question, therefore, in view of the destruction of the lumber of our country, is, what material shall be substituted for it? In a new country, with primeval forests, it was but natural that the pioneer and those who followed him in the transformation of clearings into farm lands and cities, should use the resources at hand, and lumber was the first material employed in the construction of our homes, the making of our sidewalks, the building of our highways and railroad bridges and the laying of our first sewers and water mains. As time progressed and wealth and civilization grew, materials of a more fireproof and permanent character came into use, but nevertheless the great consumption of timber kept on until the state of affairs above described has come about.

Steel, stone and brick have all been used in the developing stage of our country as substitutes for lumber, all having their advantages and all representing varying elements of cost. Within the past ten years the development of our natural resources has included the utilization of enormous deposits of land available for

cement-making, which, together with the wonderful mechanical inventions of American cement manufacturers and experts in the production of the cheapest and best Portland cement in the world, has brought about the introduction and establishment of a new, permanent and economical building material, namely, Portland cement concrete.

In considering this new material, whose name indicates its quality—CONCRETE—we must analyze what it is and of what it is composed: (1) Cement, which is the strong binding material; (2) Sand, which is the first aggregate and with which the strong binding material (cement) is primarily mixed; (3) Water, the element that causes the hydrating action of the cement upon the sand; (4) Stone, the large aggregate which is bound together by the material formed of the cement, sand and water. Thus far the actual physical elements constituting this new material, concrete, are closely defined, but there is one element of a human character that goes into the making of this new building material and which is the prime element in its successful manufacture. That element is CARE, CARE, CARE.

It would seem that in the consideration of concrete as an element of construction, it has possibly had too much treatment from the extremely scientific and engineering standpoint, and the writer desires to consider it rather from a new standpoint, namely, that of a manufactured material. In the specifications for the steel that enters into the construction of a building or bridge, every element of chemical and mechanical test is prescribed by the engineer or architect. The steel beam, girder or column is made under the most rigid supervision of chemical and scientific experts in shops or works of the most approved character, and is finally, as the completed and finely finished, fully inspected and scientifically determined, building material, delivered upon the work. This beam, girder or column is a finished building material.

In the matter of concrete the cement has been carefully manufactured in a reputable, well constructed and well officered plant. It has met the chemical and scientific tests of the manufacturer, the inspector and engineer. It is brought upon the work as a finished product so far as its bonding qualities and permanent elements as a cement are concerned. At this point, the writer contends, a manufacturing process begins, and a manufacturing process on the success of which the entire construction of the

building, bridge or other edifice depends. To this cement, so scientifically manufactured and determined, is added a sand, the requirements of which may have been covered in a couple of lines hastily thrown together in the specifications, and which, in nine cases out of ten, has had no other test than the mere rubbing of it between the palms of two hands to determine whether or not it shows clay or other coloring substances.

The stone, similarly delivered upon the job, has had no serious inspection other than possibly to know the percentage passing through a two-inch ring. The water, which may contain all sorts of deleterious substances, is seldom, if ever, analyzed, and with these three materials, the qualities of which, in nine cases out of ten, have never been determined chemically or physically, the preparation for the manufacture on the job of the finished beam, girder or column of this new material—concrete—is begun.

When it is considered that the proportion of the cement is 1, of sand 3, of broken stone 6, and the whole to be made plastic and of just the right consistency with water, it can be readily understood that at this point of the manufacturing process there is a possible chance for error in some of the ingredients other than the cement, which is the only one fully equipped at the start for its work by reason of its scientific and careful manufacture, and careful and accurate tests.

When the proposition is stated that the making of concrete is a manufacturing process on the work, every architect and engineer can readily appreciate the importance of knowing the character of all the ingredients entering into his manufactured article, and the writer's purpose in raising this point is to secure the same examination for sand, stone and water as is secured for the cement prior to use in the new manufacturing process.

When the ingredients, properly selected and tested as they would be in any well regulated manufacturing establishment, are brought together there then should come on the part of contractor and engineer the same careful attention, vigilance and thought that govern any other large manufacturing enterprise, and in the making of the beams, girders and columns and other details of a building of concrete, there should be exercised the same care, the same watchfulness and the same everlasting attention to details as is exercised in the manufacturing establishment producing the steel beam, girder or column for a similar building under simi-

lar conditions. The best illustration of the point made above is shown in the little steel beam that I have here and in the jars of the various ingredients entering into the little cement beam also shown. In the one case, all the materials entering into the steel beam have been used and the beam itself finished before it is brought upon the work, while in the other case the materials in these little jars are all separated and the actual manufacture of the concrete beam takes place upon the work itself.

Now, bearing this thought in mind, the causes of failures of concrete become somewhat clearer; they generally go to faults in construction—what I call the "manufacture" of the building. There has never been known, so far as my information goes, the failure of a complete concrete building, though the records are full of cases where such buildings have been loaded beyond the calculated strains, and where in fire they have stood exposure that would have been fatal to buildings of other materials. The failures are always in construction; they always occur through some fault in structural design or in the use of poor sand, poor stone, poor water, poor workmanship, and never in the cement itself. An examination of the reports upon the concrete failures for a single year—some five or six in number—will show conclusively that they occurred only in course of construction, in every case being explainable from one of the causes above mentioned, and illustrating as clearly as can be illustrated to the engineer and architect the point that the writer makes, namely, that the construction of concrete buildings is a manufacturing operation and requires the same care, skill and diligence as the running of any large manufacturing plant.

As illustrating this proposition very clearly, the photograph herewith shown of the failure of the Bridgeman Building, in Philadelphia, sets forth exactly the reasons of a concrete failure. In this case it was alleged that the work was carelessly done, the supports were removed too soon and many other errors committed.

One remedy, and one which is likely to come to prevent some of these mistakes, will be the manufacture of cement lumber, or beams and other forms of building construction in the shape of units, in yards or factories away from the work, and the delivery of this cement lumber upon the job, precisely as lumber is now delivered. The development of the Cerutti, Siegwart, Perrot and

other unit form systems of cement lumber is likely to be one of the great features in the growth of concrete construction.

In considering, therefore, this new building material, the writer desires to divide his subject into several heads and to deal with concrete, (1) as a structural material, (2) as an architectural material, and (3) as a decorative material.

As a structural material, concrete in its successes is too well known to need much description at the writer's hands. Building

Philadelphia building collapses. Showing weak character of supports, many of which are spliced.

statistics in this country alone disclose the fact that a great many buildings over eighty-five feet in height and from eight to sixteen stories, have been erected within the short period in which concrete has been used for this purpose and that there are numbers projected, under way or finished in all parts of the United States of the height mentioned. As to the use of concrete in reservoirs, dams, bridges, culverts, tunnels, sub-ways and all other forms of engineering construction, the scientific and engineering papers are full of accounts of such work. It is therefore of the abuses of concrete as a structural material that the writer desires to speak.

Having assumed that as a manufactured material concrete in

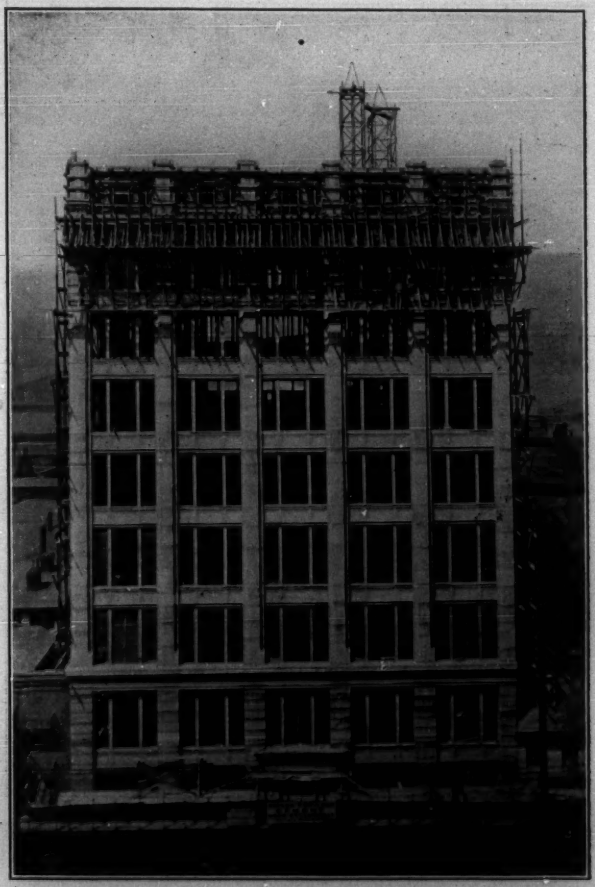
its various forms has been made of proper ingredients and with proper care, the next question comes as to the proper designing of concrete buildings. The designing, so far as the writer is aware, has rarely, if ever, been the cause of serious criticism, but it is in the carrying out of the designing that errors frequently occur. Experience has shown where columns have been improperly placed in course of construction, where beams have not been properly anchored, where reinforcing members have been put in upside down, where expanded metal has been laid with the mesh running the wrong way, and many other cases involving similar errors have been brought out in investigations of concrete construction. The results of such work are shown in the photograph of the Bridgeman Building referred to above.

As some of the concrete failures have been due to the premature removal of the timbering, there have been made a number of suggestions to obviate this, whereby, during the construction of the building, the load would be carried upon especially designed columns, and the final load would be carried by the cement used in the types of columns referred to. Thus there has been made the suggestion of a column made of sheet-iron cylinders which are filled with concrete, the cylinders carrying the load during construction and the hardened cement carrying the live load of the building when in use. Lattice columns designed by Professor Burr and used in the McGraw Building, in New York, furnishes another type contributing to the same result. Mr. Ross F. Tucker, of New York, uses for his columns large cement cylinders, two inches thick, which are in turn filled with concrete and which carry the construction load. This also forms an admirable fireproofing protection to the interior concrete and reinforcement.

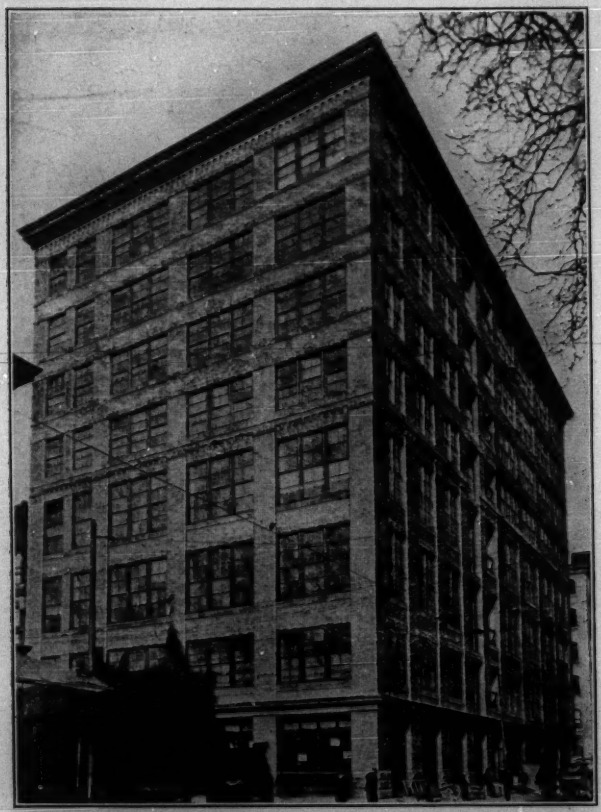
All these suggestions and improvements are likely to add much to the safety of concrete work during construction, and would obviate many of the dangers which are improperly imputed to concrete.

Another suggestion made is, that in order to prevent the removal of the forms at too early a date, the contractor should have sufficient lumber to permit of the locking of these forms for a fixed term of days or weeks, to be determined by an examination of similar concrete laid under similar circumstances under the City Building Inspector's supervision on the job itself, and that the unlocking of the forms should only be done by him or his subordinates at a time when he is satisfied that the concrete has

actually hardened. As illustrating the construction of concrete buildings under the most favorable circumstances there are shown the following:

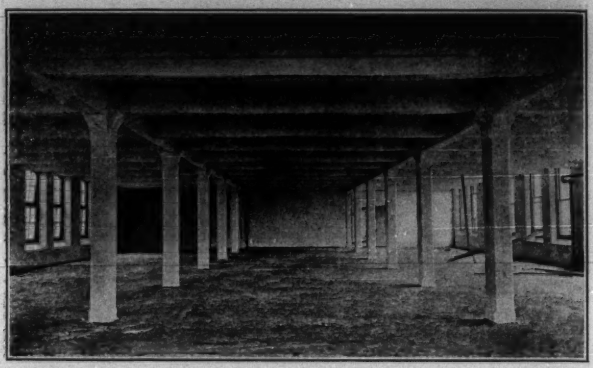


A substantial concrete building, designed by Ballinger & Perrot architects and engineers, Philadelphia.



The highest concrete building in Philadelphia. Plant of the Ketterlinus Lithographic Manufacturing Company, designed by Ballinger & Perrot, Philadelphia.

In dealing with concrete as an *architectural material,* an entirely new field has been opened up. Originally, designers of concrete houses in this country sought to make concrete tell the tale of stone, and by treating it as stone, made blocks imitating stone with which houses have been constructed in many parts of



Concrete columns and girders in the plant of the Victor Talking Machine Company, Camden, N.J. An excellent illustration of this type of construction. Ballinger & Perrot, architects.

the country. While many of these houses built of blocks are today most excellent in design and construction, there is no question that some of the earlier ones—an example of which block is herewith shown—fail in artistic beauty by seeking to imitate with

Example of block intended to represent rock surface finish.

the plastic material, cement, the rigid material, stone. Cement is capable of much greater beauty when treated as a plastic material. That blocks, however, can make a beautiful house is shown by two illustrations of the Steers Mansion, at Greenwich, Conn. This house demonstrates that block construction, when properly treated, may result in beautiful exteriors, and further proves the

The residence of J. B. Steers at Greenwich, Conn., constructed of hollow concrete blocks, made by the dry process. An example of the approved usage of the concrete block as applied to residence work. Cost $300,000.

Moyer residence. A true concrete house in which aggregate is exposed to give color and pleasing texture.

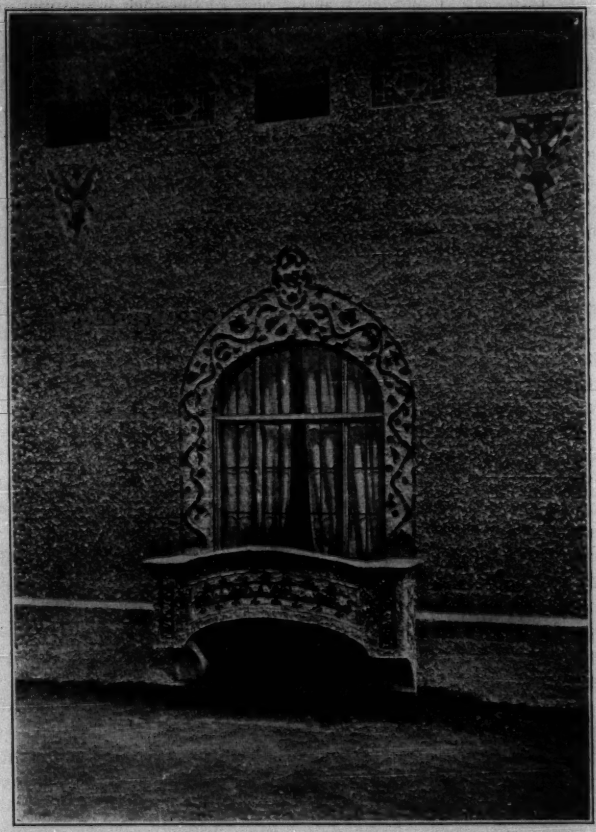
fact that the architectural defects in many of the houses of block construction are not to be charged to the blocks, but are attributable to the manner in which cement blocks have been designed or used.

It is, however, in the field of monolithic construction that concrete is doing its best work. The prominent architects, Carrere & Hastings, demonstrated the beauties of this form of construction when they erected for Mr. Flagler that beautiful group of hotel buildings at St. Augustine, Florida, and emphasized in this form of construction the antiquity and the Spanish atmosphere of that oldest American city. The adaptation of concrete to these beautiful forms of construction, its decorative features when used in combination with tiles, speak volumes for its decorative possibilities. This is also shown in the houses in Southern California, patterned after the old missions and kindred Spanish designs, red hand-made tiles furnishing the color. In the East a beautiful treatment of concrete is shown in the Moyer house, where the solid structural elements of the material are displayed, together with its decorative possibilities when encrusted with tiles.

In the artistic treatment of concrete, our architects have already learned much and are developing to-day in this great country of ours forms of concrete architecture that will be surpassed in no other country. With this material there will develop here a school of architecture, typically American, embodying within itself the beauty of the antique as well as every modern element that this day requires. The discussion of concrete at the recent meeting of the American Institute of Architects, at Chicago, shows the growing interest of the American architect on this subject and his faith in the future development of concrete construction.

So far as the use and abuse of concrete in *decoration* and treatment of surfaces are concerned, much might be written. Already reference has been made to the various methods of applying it in architectural designs and this leads naturally to the best possible treatment of the surface of concrete to secure satisfactory results. Possibly the Moyer House, which has a peculiar surface, affords one of the best illustrations of the pleasing effect to be obtained upon a concrete surface. A short description of how this was accomplished is as follows, written by Mr. Moyer himself:

"The aggregates used in the house described are composed of



Detail of Moyer house, showing application of colored clay tile on mosaic as window border with wall ornaments above. Also colored mosaics and tile.

1 part Vulcanite Portland cement, 3 parts limestone and white marble screenings about the size of sand, 5 parts of three-quarter-inch trap rock, 1 part rock and 1 part of one-inch white marble chips. When the boards were taken down the surface had the appearance of ordinary dead mouse-colored concrete, but as soon

Mercer tiles in Concrete, Bacquet Club, Philadelphia. Column of Byzantine pattern in original unplastered concrete supporting heavy ceiling. The capital is ornamented with colored tiles, glazed and unglazed, flat and in relief. Colors, yellow, green, blue, gray, red, white and buff. Tiles were applied after removal of forms and the exposed undecorated portions of column left just as they appeared after removal of forms so as to develop contrast with tiles, both in color and texture.

Concrete bridge baluster treated by Quimby process. One part cement, three parts unscreened dark stone grit.

as scrubbed and washed with a hose, all the particles of trap rock, white marble chips, bonded together by light-colored mortar, were exposed, giving a surface which was slightly roughened, and a color effect and texture which are beautiful. Photographs do

not do justice to the color of this wall; it is bright and full of life. It is a true artistic and picturesque monolithic concrete house."

The work of Mr. Quimby, described in "Cement Age" of November, 1906, is also most interesting and instructive. Some of his surfaces shown herewith suggest other methods of treating concrete surfaces.

Mr. Henry C. Mercer has also developed in the Racquet Club, Philadelphia, practically a new school of concrete decoration and artistic treatment. Some of the accompanying illustrations show what can be done with cement and tiles by treating concrete frankly, even though these views indicate imperfectly the importance of this work, for you must picture to yourself the brilliant color of the tiles and the contrast between the dull gray of the cement and the mass of decorative color embedded within it.

So far as the abuses of concrete surfaces are concerned, the cast "cut-stone" blocks above referred to are fair illustrations, and it may be stated as a broad proposition that concrete is concrete with its own tale to tell and has a surface of its own to speak for itself, and wherever this surface is changed into some other material or some other surface, imitating some other material, it is very likely to be wrong from a decorative and artistic standpoint. The exception is where it is hammer dressed or cut by tools, as in the case of stone. This is an important distinction I wish to emphasize. Given two blocks of stone, one of concrete or artificial stone, and the other natural stone, it is manifestly possible to have them equally meritorious by cutting both or treating them in the same fashion, for in surface decoration we have by this method removed concrete from the domain of a plastic material. But when we attempt to reproduce this cut surface by casting it in a mold, then we do violence to a plastic process or art which results in monotonous repetition. Of course, this does not apply to columns, capitals or cornices. I am speaking of broad surfaces in monolith or made up of many units.

In conclusion, the writer can only add that from a long experience in the cement manufacturing industry, dating back to its pioneer days, in the early seventies, he has seen the growth of the industry himself and the growth of all the uses of this wonderful material, cement, and looking back over the long period covered by his connection with the industry, he has seen the great growth of concrete construction in all its forms to a degree beyond the

Mercer tiles in Racquet Club, Philadelphia. View of detail in Gothic fireplace adapted from original of the 14th century in castle at Trebbio, district of Sicci, near Florence. Frieze, banding and columns composed of glazed and unglazed tiles applied after the construction of the fireplace. The flatness of the large concrete area or face is broken by widely placed relief tiles silhoutte.

expectations of the most sanguine. He has seen concrete gradually take the place of other materials because of its great strength, its fireproof qualities and its economical elements. He has seen it develop from the architectural and engineering standpoint; he has seen it grow in decorative and artistic possibilities, and it is his conclusion that concrete honestly, carefully and properly made, in buildings properly constructed and designed, will, with the present knowledge of the architectural capabilities and the artistic qualities of concrete, ultimately supersede for most uses the present materials of construction.

AMERICA USES MANY BARRELS.

Upwards of 150,000,000 barrels and circular packages are manufactured in the United States annually. Few people, except those whose business it is to know, realize the extensiveness of the cooperage industry in this country.

The heaviest demand comes from the cement business. The flour business ranks next, closely followed by sugar. Containers for fence staples, bolts, nuts, nails, and packages for roasted coffee, spices, crockery, fruits, vegetables, follow in the order named, while glass manufacturers, baking powder companies, liquor distillers, and candy, tobacco, and cheese packers are big users of barrels. The demand for barrels for molasses, oil, lard, and pork is also enormous, while dry paint, glue, snuff, oatmeal, screws, castings, and general hardwood articles annually increase the demand on the cooperage supply.

While the amount of expenditure for barrels can be quite closely estimated for a given year, it is not possible to say how many barrels are in actual use. The life of a barrel is put down at one year by the trade, but this is far from true. A majority of barrels are used many times. They begin as sugar or flour barrels, and are then sold to the farmer for shipping his produce to the market. It may be that they are returned to him several times, carrying potatoes to the market on the first trip, and tobacco or lettuce on the next, each cargo being lighter in weight than the previous one, owing to the weakened condition of the barrel. Finally the barrel may serve out its work as a refuse receptacle, and in the end can be used for fuel. Thus, it may be said, that a barrel fills as useful a career as almost any other manufactured article, and its life is much longer than a season.

The demand for barrels is steadily growing because modern machinery has made it possible to make them for the trade cheaper than almost any other form of durable package. That it is the most convenient form of package has long been acknowledged. The timber used in tight barrels has to be selected with care, as it must not only be water-tight, but barrels for the oil, whiskey, and paint trades in addition must be capable of resisting high internal pressure. The lumber used for this work must be carefully selected, that cured by slow air drying under shelter being the most satisfactory.

Mechanical and Engineering Section.

"A Wheel In the Middle of a Wheel."

Waterway Legislation.*

By Lewis M. Haupt, C.E., A.B., Sc.D.

In the May number of the *Journal,* attention was called to the comparatively undeveloped condition of the waterways of the United States and the efforts which were pending to so modify the National policy that they might be improved more systematically.

With no uncertain sound the President has laid stress upon the necessity for regulation and relief of the transportation system of the country, stating that "The rivers of no other civilized country are so poorly developed, so little used, or play so small a part in the industrial life of the nation as those of the United States." He has appointed the distinguished commission, which presented its preliminary report February 26th, 1908, to the "First Session, Sixtieth Congress (Senate Document No. 325)," which report was submitted with a view of urging early action by Congress looking to immediate relief. A bill was introduced in the House of Representatives to perpetuate this Inland Waterways Commission, by its Chairman, Hon. Theodore E. Burton, and appropriating $20,000 for its expenses in pursuing investigations, which bill passed the House with only two negative votes, but failed of approval in the Senate. In commenting on this defeat of so necessary a measure the "Engineering News" of June 4th, says editorially: "Is it possible that the Senators prefer the present lack of system, with its barter and sale, its log-rolling and its many opportunities for political manipulation?"

The question is left to be answered by the people. It would seem, however, that notwithstanding the great popular movement which has been held during the present session and the all-but

* Read by title.

unanimous demand for $50,000,000 annual appropriations for waterways, the attitude of Congress is uncertain and action is deferred on the ground that the "public sentiment" will not justify such expenditures.

This is the more remarkable in view of the action taken by the great and enthusiastic Waterways Congress held in Washington, December 4-6, 1907, which was presided over by the Honorable Jos. E. Ransdell, M.C., of Louisiana, when the following resolutions were reported, "representing the sentiments of thirty-seven State and Territorial representatives:"

Be it resolved; First, That we earnestly urge the adoption by the Federal Government of a wise, liberal and comprehensive waterway policy that will provide for the proper improvement, within the next ten years, of the rivers, waterways and harbors of our country, the improvement of which *is justified** by present and prospective benefits to commerce.

Second. That without presuming to prescribe the engineering or the financial details of this great undertaking, this Congress strongly urges upon the Congress of the United States the importance of the *immediate adoption of a comprehensive plan of waterway improvement,** of the carrying on of the work by an adequate number of engineers, and of such liberal appropriation annually as will insure the early completion of such objects as may be undertaken.

Third. That we cordially endorse the action of President Roosevelt in appointing a special Inland Waterways Commission, being confident that the report will prove a source of accurate and valuable information to the American people. We further recommend that Congress enact such laws as will make the Inland Waterways Commission permanent, and will provide it with necessary authority for its investigations and recommendations.

Fourth. That this Congress cordially thanks President Roosevelt for the support he has given to its purposes, by his speeches, and by his treatment of the subject in his recent message to Congress.

Fifth. That we ask Congress to view the river, waterway and harbor appropriations not as the appropriation of money for current expenses of government, but as an investment in perma-

*The italics are the writer's.

nent improvements, bound to pay increasing dividends from year to year. Viewing these appropriations in this light Congress is fully warranted in authorizing an annual expenditure, beginning at the present session, of not less than one-tenth of the amount of money required for all the various rivers, waterway and harbor improvements already planned and approved by the engineers in charge or hereafter planned and approved, in order that the work may be carried to speedy completion, such appropriation to be not less than $50,000,000 annually, and Congress is further warranted in authorizing the expenditure of the money as needed, and in providing for the same, if in excess of funds available, by a bond issue similar in character to that for the building of the Panama Canal, whereby part of the cost of these vast improvements will be spread over a succession of years, and borne by all who share the benefits. Signed, J. Hampton Moore, Chairman Committee on Resolutions.

Nearly two thousand delegates were present, representing all classes of interests and industries from all parts of the Union, and the feeling was very pronounced as to the *necessity for immediate action,* yet within six months of that date Congress has adjourned without passing either a river and harbor appropriation bill or even providing for the support of the Commission to prepare a definite policy for these vitalizing improvements.

Is the partisan, political aspect more potent than the urgent request of the business interests of the nation at this critical juncture?

Many local organizations have taken similar action, but suffice it to refer to the action of the National Business League of America, which at its meeting held May 25th, also passed a series of resolutions covering the larger scope of our public utilities for the consideration of which the first conference of the Governors of the several States was held at the White House from the 13th to the 15th of May. They read: "*Resolved,* That * * * (we) recommend the forwarding of the following economic public measure, of grave importance, as involving the future welfare of the American people.

First. Systematic conservation and reproduction of the forest reserves, for the perpetuity of our water courses, water powers, agriculture, industries and commerce, and for the prevention of disastrous floods and erosion of the soil.

Second. Reclamation of arid lands by irrigation and of swamps and overflowed lands by drainage.

Third. Equitable distribution of arable lands in small farms, to home builders only.

Fourth. Husbanding of oil deposits; of coal, copper, iron, and other products of the mine.

Fifth. Construction of better common highways from the farms to the mills and markets of the country, and creation of a comprehensive system of navigable inland waterways by the Commonwealths and the Nation.

Sixth. Cöoperation of art with nature to enhance the beauty of the landscapes, the nooks and by-ways and to create more healthful conditions for the people.

Seventh. Enactment of national statutes to adequately cover the measures herein recommended and repeal of all laws in conflict therewith."

This last recommendation, being paramount to any progress, should be considered first, as it involves the entire question of authority, jurisdiction, means and method. As the determination of these details have so long hampered the normal progress of our country it is of prime importance that a few fundamental principles be established in the hope that they may point the means to the end.

It is indubitably desirable that the organized, constituent bodies of the States and Nation should devote as liberal a percentage of their revenues to the creation and conservation of public utilities, to be leased and operated if desired under corporate management for a term of years.

It is unwise to attempt to centralize these great and multifarious operations under one extrinsic authority, requiring approval of plans, details and organization, or of appropriations from the national treasury, in a country reaching more than half way around the globe.

Experience has demonstrated the futility of such attempts by the failure of many urgent projects because of the impracticability of meeting the demands from all sections, for ample appropriations or by the opposition of hostile vested interests, fearing competition. Thus, a State or Nation undertaking to direct all industries would be overwhelmed in a short time and its machinery would be paralyzed.

There must be a careful segregation of the duties and powers of government, which are supposed to rest with the people from whom they are derived, so that they may be intelligently and promptly applied to the needs and resources of any locality as they may exist at the time.

This spirit of Government has been concisely stated by John C. Calhoun in his address to the Memphis Conference many years ago, when the nation was young. He said: "It was the Genius of our Government, and what was to him its beautiful feature, that *what individual enterprise could effect alone, was to be left to individual enterprise; what a State and individuals could achieve together, was left to the joint action of States and individuals; but what neither of these, separately or conjoined were able to accomplish, that and that only, was the province of the Federal Government.*"*

The safety of this policy which was pursued up to the time of the Civil War, will be seen by reference to the legislation of those ante-bellum days when there were no dominant industrial interests to check development. They present a striking contrast with the present failure to pass any bills looking to the relief of commerce or the restoration of our merchant marine, yet about $400,000,000 are applied at the session just closed to the devastating art of war and its sequence, pensions, which latter item has been increased about $20.000,000 at the recent session.

This failure to provide for waterway improvements or for the continuation of the Commission to consider methods of relief for our domestic commerce, is significant of the helplessness of Congress, where the responsibility is divided, hence the words of Senator Knox will bear repetition in view of the sequel: "When the Government assumed charge of the navigable streams of the interior it entered into a practical contract with the States and communities bordering these streams that their waterways would be improved to their highest capacity. The States were thereby prevented from improving the streams themselves.

"Corporate enterprise was forbidden to undertake the canalization of important stretches and fix the cost of their works and franchises on the traffic. The Federal Government has made its formal and deliberate declaration that it will do this work. That

*The Manufacturers' Record, April 30, 1908.

necessarily involves that it will make the improvements adequate to modern needs and possibilities. To do any less would be a mockery and breach of good faith."

The question immediately arises as to whether the "*assumption*" of jurisdiction over water lying wholly within a State, and without her consent, constitutes a valid contract? It would seem that, regardless of such legislation by some former Congress, many of the States have definitely ignored such a construction of the Constitution, and are expending large sums upon their own internal improvements, in accord with the authority specifically reserved by them when they ratified the Constitution of the United States. Then it was stated, Amendments, Article X:

"The powers not delegated to the United States by the Constitution, nor prohibited by it to the States, are reserved to the States respectively or to the people."

The powers thus delegated are stated in Article I, Section 8, where eighteen specific acts are enumeratd, amongst which are "(3) to regulate commerce with foreign nations, and among the several States and with the Indian tribes." The rights of the people are still further guarded by the Ninth Amendment, which states that "The enumeration in the Constitution of certain rights shall not be construed to deny or disparage others retained by the people."

Yet, under what is characterized as the "law of expediency," the functions of a centralized, extrinsic control have been gradually extended over all waterways, improved or otherwise, to such an extent as to have paralyzed local efforts, under the delusion that some day and somehow the Nation may provide the long-desired relief, and the Nation replies: "Not so long as there is not sufficient tonnage to justify an appropriation."

In this connection it is well to note that it was to prevent "rate-cutting" between the several States that the constitution was adopted, but not to construct lines of internal communication under Government control or by Executive authority, and that this idea was so firmly impressed upon the early Presidents that Thos. Jefferson in his Message to Congress of December 2, 1806, recommended that authority be vested in the Government by an amendment providing for the use of the public funds in certain cases—in the building of roads, improvement of rivers and for public education and other improvements; while President Mon-

roe vetoed a bill making appropriations for rivers and canals on the ground of its unconstitutionality. As will be seen later, however, the policy of lending aid to the States and corporations under them extensively prevailed up to about the time of the civil war, when the Government extended its jurisdiction over internal improvements and transportation.

RETARDATION OF NATIONAL RESOURCES.

The proposition to further extend the powers of the Government to divert the revenues to be derived from the water-powers of the States into the National Treasury, is shown by the several bills which were introduced at the last session, of which it is said, "None of them gives the Government the right to make a reasonable charge for the valuable privileges so granted, in spite of the fact that these water-power privileges are equivalent to many thousands of acres of the best coal lands for the production of power."

In this comparison of relative values it should be observed that the use of the water in a mill or factory, merely for the dynamic energy which it gives out, is an indestructible property, which is not impaired in the using, nor is the quantity of the water diminished by its temporary diversion through the flume or penstock of the mill. It flows on forever to the sea and it returns by natural agencies to the place whence it came, that it may bless the nations of the earth. It is now proposed to tax this Divine benefaction, thus adding to the cost of the operation of the power plants and their products and compelling the manufacturer to collect from the people the revenues he must return to the Government for the opportunities he may wish to utilize in his business. Thus an obstacle is to be placed *"in restraint of trade"* by charging for a franchise which is now running to waste and which might be utilized without impairment, for the benefit of humanity and the peaceful employment of labor, or the distribution of power to remote localities.

With the coal fields the case is entirely different. Their energy once consumed, ends in smoke and cannot be returned. Timber, however, has an inherent power of reproduction, and by conservative management may be able to replace itself, if protected from wanton waste and fires. This is now being done

largely by the States and the Government, under its most efficient Chief Forester, while it is notable that efforts to secure the great Appalachian reserve by National legislation, have thus far failed.

The enormous advantages possessed by the great water-powers of the country have not been appreciated as they should have been, because of the large sums invested in coal and timber properties and in the transportation of those products, and a tax on water-powers means a heavy draught on the coal and lumber, but their rapid extinction will ultimately compel the utilization of the ascendant power as a cheap substitute for many of the industrial operations of mill and factory. Probably no one agency will have a more beneficial effect in retarding the destruction of our coal and timber resources than the more general use of water-powers for long distance transmission, whether by electric or compressed air conduits. To this end *liberal legislation should be encouraged, and no unnecessary restrictions should be placed upon the utilization of these powers, either by the National Government or by the States.* Even where dams are built for the purposes of navigation, the power thus generated could be freely given to encourage the establishment of industries, from which the Government or State would derive its returns in other forms of taxation as at present.

THE POLICY OF PUBLIC WORKS.

In a comprehensive review of the policy of the Nation in reference to its waterways, "Shipping Illustrated" of April 4, 1908, remarks that according to the President, "No single agency has been responsible under Congress for making the best use of our rivers, or for exercising forethought in their development. In the absence of a comprehensive plan, the only safe policy was one of repression and procrastination." Yet it may be noted that many Boards and Commissions have been appointed from time to time, and very large sums have been expended in tentative efforts to better the navigable channels with results which he has declared to be inferior to those of any other civilized country—"largely negative." The policy of repression and procrastination continues—and the consistent plans are not formulated but left "to the whims of politics and the vagaries of the steering committees at Washington"—of which Prof. F. J. Stimson, in his analysis of the *"American Constitution"* says: (p. 90.)

"I would now call attention to the fact that the phrase 'Commerce among the several States,' one of the only three phrases in all the powers given to Congress which are not purely political, under the interpretation proposed by President Roosevelt, would alter our Constitution more radically than almost any amendment could do. It will cease to be purely political, but will thrust its hand between every man and his neighbor, between every man and his own property. * * * The States will lose control of most of their business affairs, will *lose the power to tax their own enterprises,* will see their courts shorn of their jurisdiction."

"Hardly any business will be so small, so local, as to be left to the State power to control. We shall all be under the Government of Washington * * * quite as completely and much more hopelessly than the English of the twelfth century were under the power of the royal chief justice of the Norman kings."

And as to the alleged necessity for applying to Congress for the right to make waterway improvements under this clause of the Constitution Prof. Stimson very clearly states:—

"No powers can be delegated by the United States to the States, or still more to the people. It is the other way about. It is the people of the States who delegate powers to the United States. Again * * * to relegate a political power to the States, misstates the principle of the American Constitution. The Nation can relegate nothing to the State. It is the State or the people that delegates powers to the Nation."

So that, falling back on the *lex loci,* which is as old as the Constitution itself, it is found that the right to make improvements in the waterways of the land, of chartering corporations under State authority, for this purpose, of charging tolls thereon or of selling the powers generated thereby, have ever been the inherent property of the States and their citizens, and they have never been relegated to the Nation. Any trespass upon these rights would be in violation of the sovereignty of the States.* Numerous legal opinions might be cited in support of both the law and the policy of such local control and development. The following is pertinent:

The early demand for deeper water in the Ohio River, at all seasons, led to frequent propositions for its improvement, and

*See Shipping Illustrated, 116 Produce Ex., New York, April 4.

many conflicting opinions were advanced as to methods and cost. In these the officials of the Pennsylvania Railroad Company took an active part, and in 1855 a system of canalization by low dams and restraining reservoirs with chutes was proposed, but the interferences from political sources were so great that it was concluded that it were "better to let the Ohio remain forever unimproved than, if improved, to be managed and controlled by partisan agencies." We fully concur in the opinion expressed by the Hon. Jeremiah Black of the Supreme Court, that the improvement should be made and managed by a company, to be formed of citizens under a charter approved by all the States bordering on the Ohio. * * * The general Government can well afford to make a liberal appropriation in consideration of being forever released from the present annual expenditures. The States immediately interested should do something and be entitled to a representation in the direction, and individuals would do the rest. The rates of toll should be restricted to such an extent as to afford no greater revenue than will suffice to keep the work in proper condition, and pay the shareholders moderate dividends.

In further illustration of the well-established policy of Government aid to States and corporations, the following extracts are taken from the able compendium of Hon. B. F. Frovel, of Georgia, relative to the proposed Atlantic and Great Western Canal, across the Piedmont plateau, which is again being urged as a short cut from the Tennessee River to the Georgia Coast.

In this report, submitted January 18, 1873, to the House of Representatives of the Forty-second Congress, Third Session (Mis. Doc., No. 52), he says: "Believing, as I do, that Congress possesses the right to appropriate money for such a national object, *the jurisdiction remaining to the States through which the canal would pass,* I submit it to your consideration. (House Journal 1823-24, pp. 19 and 20)" * * * It appears from the journals of that date that this object did receive consideration, and that these deliberations resulted in the following Acts:

April 30, 1824. Appropriating $30,000 for the survey of canals and roads.

May 26, 1824. Authorizing Indiana to open a canal through *public* lands connecting the Wabash and Miami Rivers.

March 3, 1826. Authorizing a survey of a route for a canal connecting the Atlantic and the Gulf of Mexico.

April 14, 1826. Authorizing Pennsylvania to construct a canal through the public ground near the city of Pittsburgh.

May 13, 1826. Subscribing $100,000 to the Louisville and Portland Canal Co.

May 18, 1826. Subscribing $60,000 to the Dismal Swamp Canal Co.

May 2, 1827. Granting land to Indiana for a canal to unite the Wabash River with Lake Erie.

May 24, 1828. Granting land to Ohio to extend the Miami Canal from Dayton to Lake Erie.

March 2, 1829. Subscribing $75,000 to the stock of the Chesapeake and Delaware Canal Co. and $20,000 additional to the Dismal Swamp Canal Co.

March 2, 1829. Subscribing $135,000 additional to the stock of the Louisville and Portland Canal Co.

April 2, 1830. Granting lands to the State of Ohio to construct canals.

February 12, 1831. Authorizing Alabama to contract for and construct a canal around the Muscle Shoals (on public lands).

May 29, 1830. Granting lands to the State of Indiana for the Wabash and Erie Canal.

May 2, 1831. Authorizing Florida to open a canal through public lands.

July 4, 1832. Providing for a survey of a canal route from St. Andrew's Bay to the Chattahoochee and Pensacola Bay and along the northern coast of the Gulf of Mexico.

March 2, 1833. Granting lands to Illinois for a canal to connect the Illinois River with Lake Michigan.

February 27, 1841. Granting lands to Indiana for the Wabash and Erie Canal.

March 3, 1845. Granting additional lands for the same purpose.

June 30, 1834. Granting lands to Ohio for the Wabash and Erie Canal.

June 18, 1838. Granting lands to Illinois for the Illinois and Rock River Canal.

April 10, 1866. Granting lands to Wisconsin for the breakwater and ship canal.

August 26, 1852. Granting lands to the St. Mary's Ship Canal, Michigan.

March 3, 1865. Granting lands to the Portage Lake and Lake Superior Ship Canal.

July 3, 1866. Additional grants for the same purpose.

July 3, 1866. Granting lands for a canal to connect Lake Superior with Lac La Belle.

"Since then the Des Moines Canal, the Fox River and Green Bay Canal, the canal around Sauk Rapids, the Illinois and Michigan Canal, and other works of similar character have received Federal aid, either directly by appropriations of money or by grants of land from the Treasury. As early as 1809, we find that an appropriation was made for the opening of a canal from Lake Pontchartrain to the Mississippi as a defensive means. These several Acts, extending through every administration from Madison down to the present time, would seem to show that it has always been the policy of the Government to aid and foster these enterprises, as not only necessary and contributing to the National defense, but essential to our commercial prosperity."

The enormous land subsidies made to private corporations to encourage the construction of the overland railways serve to enforce this National policy, under which the rail transportation interest has been so carefully fostered that it has become the greatest in the world, but unfortunately the child has become the father of the man and has so far throttled his benefactor, the waterway, as to have almost destroyed his development, by centralizing the control of his growth and denied him the necessary alimentation from the National crib. To-day the policy seems to be reversed and to require a preliminary contribution from the localities desiring improvement before consent may be obtained in some instances even for the requisite surveys. The astounding result has been that under the old régime about 5000 miles of canals and improved waterways were constructed and in operation at a cost to the Government of less than $15,000,000; while under the new it has expended more than $550,000,000 on its rivers and harbors, while the interior canals and slackwater improvements have decreased in mileage about fifty per cent.

PROPOSED LEGISLATION.

The late congestion of the overland traffic, resulting in serious delays, has called for relief by water, and to this end numerous bills have been presented looking to a complete reorganization of

the system of conducting these works and the placing of their control on a more permanent basis under the National Government, but still subject to frequent changes of personnel and the distribution of an enormous patronage by the Executive Departments, without whose consent first being secured no such works may as a rule be undertaken.

A fair idea of the scope and power to be conferred upon the Executive by the Legislative Department and the manner in which the latter may be subordinate to the former, or the reverse, according to whether the issue may be an approval of plans, or of securing appropriations of sufficient amounts to be effective, may be seen from a brief digest of one of the bills to create a Department of Public Works, to which shall be transferred a number of the Bureaus from other departments, and to empower its Secretary, a Cabinet officer, to make investigations and reports, and "*only in so far as may be authorized by Congress,* to carry out such plans and to construct and maintain the necessary works."

"That the skill and ability acquired by the energies of the Army shall not be lost to the Government, and that their services may be rendered the more valuable in time of war, provision is made whereby the President may detail officers of the Army, as well as employees and officials of other Executive departments, to duty in this one * * * that the officers of the Army shall not only have opportunity for the planning and erection of hydraulic works, but shall also have opportunity for actual work upon those branches of engineering which will most fit them for their duties as military engineers, namely, upon topographic surveys, the construction of embankments of earth and works of masonry, the construction of highways and the investigation of railway and transportation problems, as would be possible under this bill by assignment to the duties (of the civilians) in the Bureau of Waterways, Geological Survey, Reclamation of Coast and Geodetic Survey, of Mining Technology and of Transportation."

This would indeed be a fine school of practice for the training of experts in military engineering, but it might seem pertinent to inquire what is to become of the many duties pertaining to that Bureau, *ad interim,* when "it is stated by a prominent officer of the Engineer Corps that to properly carry on all the important work now assigned to that corps * * * the personnel should

be increased by at least one hundred officers at once, and this estimate is believed to be too small."

Among the existing bureaus or works proposed to be transferred to this department are the following: The office of the Supervising Architect of the Treasury; the Geological Survey; the Reclamation Service of the Interior Department; the Coast and Geodetic Survey of the Department of Commerce and Labor; the Bureau of Standards; the Superintendence and Care of the Capitol Grounds and Buildings; the powers and duties of the General Land Office in respect to surveys of public lands. There is to be created in addition a Bureau of Mining Technology, to test materials and investigate waste in mining operations; also a Bureau of Transportation, to investigate all matters relating to railway and waterway transfer facilities and the regulation thereof as to sites and location of tracks, grades, bridges, &c., and to exercise oversight as to the terminal facilities of ports; also the office of Public Roads from the Department of Agriculture, to coördinate the highways of the country with other transportation routes; also the duties now vested in the Inter-state Commerce Commission so far as it has to do with statistics, but leaving all of its judicial functions to another department; also a Bureau of Coördination to classify, tabulate, compile and publish all data relating to the operation and investigation of the various bureaus and offices of the department and to coördinate the works of the various bureaus with kindred works in other executive departments, especially with those relating to Irrigation, Swamp Lands, Reclamation, Water-powers, Prevention of Soil Waste and Erosion, Preservation of Forests, &c. It is also proposed that this bureau shall conduct investigations and oversee coöperative arrangements between the Federal Government and States, municipalities, corporations, &c., which may arise pertaining to the irrigation or drainage of lands, the investigation of mining industries, the oversight of terminal, trackage and wharfage facilities, erection of public buildings, &c. Provision is also made for an Assistant Attorney General and an Auditor for said department.

Such, in brief, is the proposed new element of an already complex Government, having within this department an independent bureau to regulate all related functions, with fiscal and judicial officers, executive and administrative chiefs, and yet unable to execute plans or works unless approved by the chief of the bureau,

the President of the United States and the Congress. To exercise civil power, largely under military control, yet not subordinate to the War Department directly, which powers have not been conferred upon the National Government by the States nor the citizens thereof.

It remains to be noted that this bill places the responsibility of appointing this small army of employees and officials upon the President, and the salaries range from $12,000 per annum for the Secretary, down to that of the lowest employee. The several chiefs of bureaus may have "legal, clerical and special assistants, and such chiefs of divisions, senior clerks, clerks, junior clerks, under clerks, sub-clerical employees, professional and special employees, experts, &c., as may be authorized by law."

The governor of this complicated mechanism is to be the "Commissioner of Coördination," with a salary of $6000, and an "Assistant Director," appointed by the President, with a salary of $4000, who will be the wheel in the middle of the wheel.

"GOVERNMENT BY COMMISSIONS."

Another measure, far less pretentious, was introduced to vest in the President the authority to appoint an Inland Waterways Commission "to bring into coördination therewith the Corps of Engineers of the Army, the Bureau of Soils, the Forest Service, the Bureau of Corporations, the Reclamation Service, and other branches of public service related to waterways, and to appoint such experts and other persons and create such board or boards in connection therewith as the work may require, and to fix the salaries of all commissioners, experts and other persons employed under this Act until the same has been fixed by Congress." Such commission shall make examinations and reports, and "if after such examinations, survey and estimate such commission shall determine that any project for the improvement or construction of a waterway is practicable or desirable, it may, with the approval of the President and through the appropriate service construct or execute, or cause to be let, contracts for the construction of the same, &c.," *Provided*, that the necessary moneys therefor are available in the inland waterway fund. This fund is to be supplemented by contributions from States, municipalities, corporations,

&c., and from the sale of reclamation rights, water-powers and other available assets.

Thus all sections of the country desiring improvements of this class would be compelled to besiege the Commission first for examinations, surveys and reports, followed by appropriations, if endorsed, provided there were sufficient funds available for completion. How many years would elapse before a work of any magnitude would be installed can only be determined from past experience, which has demonstrated that from five to fifty years may roll away, and even then the work may not have been begun, because of the superior demand from other and more potent agencies, while projects of no public utility have been approved for political patronage.

The failure of all legislation affecting increased water facilities at the session just closed is evidence of the delays which beset the efforts to conduct such improvements from a single, central source with so many conflicting interests at stake. If the country is to keep pace with the demands for transportation due to its great output of industrial and agricultural products, it is imperative that some radical and liberal legislation should be speedily enacted to stimulate local initiative, as in the pristine days of the Republic.

WOOD PRESERVATION AND THE PROCESS OF PRODUCING CREOSOTE OIL.

One of the significant signs of the times is the awakening of the American people to the dangerous destruction of their forest wealth. and the necessity of a wise use of what remains of it. Undoubtedly, in the future the nation must utilize its forest crop less wastefully, both in the woods and in the mill, and must make provision for future crops; but that is not the only way to prolong the timber supply. If the service of the wood which is used can be lengthened, it will largely decrease the amount of timber which must be cut. And this can be done, by treating the wood with chemicals which will poison the low forms of plant life which attack it and cause it to decay. The growth of timber is slow, and when the dearth of it becomes pressing, a new crop cannot be grown quickly enough to prevent a time of severe shortage. Preservative treatment of timber has the advantage, as a remedy, that it can be applied immediately. Its importance is therefore attracting increasing attention.

Many chemicals have been used for the preservation of timber, among them being blue vitriol, corrosive sublimate and chloride of zinc. The

most effective preservative is the substance called "creosote oil," or "creosote." On account of the similarity of the names, many people suppose this to be the creosote obtained from wood, such as can be obtained, refined for medical purposes, at the drug stores. But the two are quite different, and should not be confused. The creosote used in wood preservation is obtained from coal, by a most interesting process.

Nearly every city now uses gas for light and fuel, and many people know that this illuminating gas is often made from coal. But the many things besides gas which are obtained in this process are not so well known. It is one of these other products from which is obtained the creosote oil used for wood preservation.

To understand how all these things are produced, it is necessary to know something which the chemists can tell us. Coal, they say, is composed partly of the substance called carbon, partly of compounds of this carbon with the gas hydrogen, which they have named "hydrocarbons." When the coal is heated sufficiently, away from air, the hydrocarbons are driven out in the form of gas. Illuminating gas is made by subjecting coal of the proper kind to this process, which is known as "dry distillation." The coal is put into a long, fire-clay oven, or "retort," shaped much like a giant model of the little cakes which the bakers call "lady fingers," the retorts being about thirteen feet long, two feet wide and sixteen feet deep. A number of these retorts are built side by side, in three rows, one above the other, the ends of the retorts being supported in a brick wall, which also extends around the ends of the rows and over the top, and thus entirely encloses the retorts. Fire, from furnaces below, is carried by flues into this enclosure, so that the retorts are entirely enveloped in flame and can be heated to a very high temperature.

The retorts are partly filled with coal, after which they are sealed, so that no air can get into them. They are then heated to a temperature of about 2,100 degrees, F. Under this intense heat almost all the hydrocarbons of coal pass off, leaving behind only the "fixed" carbon, which comes out of the retort as coke. Many of the lighter compounds distilled off by the heat now remain in the form of gas when they are cooled to ordinary temperatures, and it is some of these which make the gas finally used for lighting and fuel. But as it comes from the retorts the gas is like a thick, yellowish-green smoke, and could not be used at all for such purposes. This gas escapes from the retorts into a series of large and costly machines where the lighter gas is cleansed from its impurities, and the different by-products are separated from each other. First are great "condensers," in which the gases are cooled. The cooling condenses the heavier compounds into thick liquids, which are then left behind.

One of the substances later removed from the gas is ammonia, and from such gas works comes the ammonia water which is used in every household. Another important product of the gas making process is the coke which is left in the retort. Every year an increasing number of people use this coke for burning in kitchen stoves, and even in furnaces, instead of coal, for it makes a very hot fire and burns without any smoke.

The heavy, strong-smelling, black liquid which is collected in the cooling

of the gas is what we know as coal tar. This is an exceedingly complex mixture of substances. From it are obtained not only creosote oil, but most of the dyes which are used now-a-days, perfumes, and even flavoring extracts.

Gas, coal tar and coke are also made in what is known as the by-product coke oven, which is adapted to different objects, but is operated on the same principle. Its coal tar is equally as good as the gas works tar for making creosote oil. In recent years a great amount of gas has been made in the United States by another process, and is known as water gas. This process also produces a tar, which looks much like coal tar and is often difficult to tell from it. But this tar is really derived from petroleum, and does not make a good oil for preserving wood from decay. Wood creosote, with which so many people are familiar, is likewise obtained from a wood tar, which is produced by distilling wood. But like water gas tar creosote, wood creosote is not so good for wood preservation as is the coal tar creosote. When creosote is bought for that purpose, therefore, it should be certain that it is coal tar creosote.

To obtain creosote oil from coal tar, the tar is, in turn, distilled. But this distillation is like that used for other liquids instead of that employed for the coal. The still is heated, and as the heat increases the "light oils" first pass over. Among these is the familiar carbolic acid. This is a powerful antiseptic, but it is not desirable in a wood preservative, for it evaporates so readily that it soon becomes lost from the wood. When a temperature of about 400 degrees has been reached, the distillate is turned into another receiver, and from this point on to 600 or 700 degrees creosote oil is produced. One of the substances which is contained in this mixture is "naphthalene," from which common moth balls are made. Coal tar creosote, thus produced, is the great wood preservative.

The residue remaining in the still after the distillation is "pitch," which is used chiefly in the preparation of roofing felt. In America roofing pitch is the chief end for which tar is distilled. In Europe this is not so true. Now pitch for roofing must be rather soft. Therefore tar distilllation is not carried so far in this country as it is in Europe. For creosote oil it would be better if it were carried farther, since the substances which distil at the higher temperatures, in most cases, neither evaporate in the air nor dissolved in water as readily as those which distil more readily. Consequently they stay in the wood for a longer time, and protect it correspondingly longer from decay. Much study has been devoted by the United States Forest Service to creosote oil, to determine what its composition should be to give the best results in preserving timber, under different conditions, and how the most desirable creosotes may be obtained. The reports of these studies, together with detailed description of the more economical processes of applying the preservatives to wood have been worked into circulars which the Government has placed at the disposal of users of timber and which will be furnished to all who make the request of the Forester at Washington.—*Bureau of Forestry—U. S. Dept. of Agriculture.*